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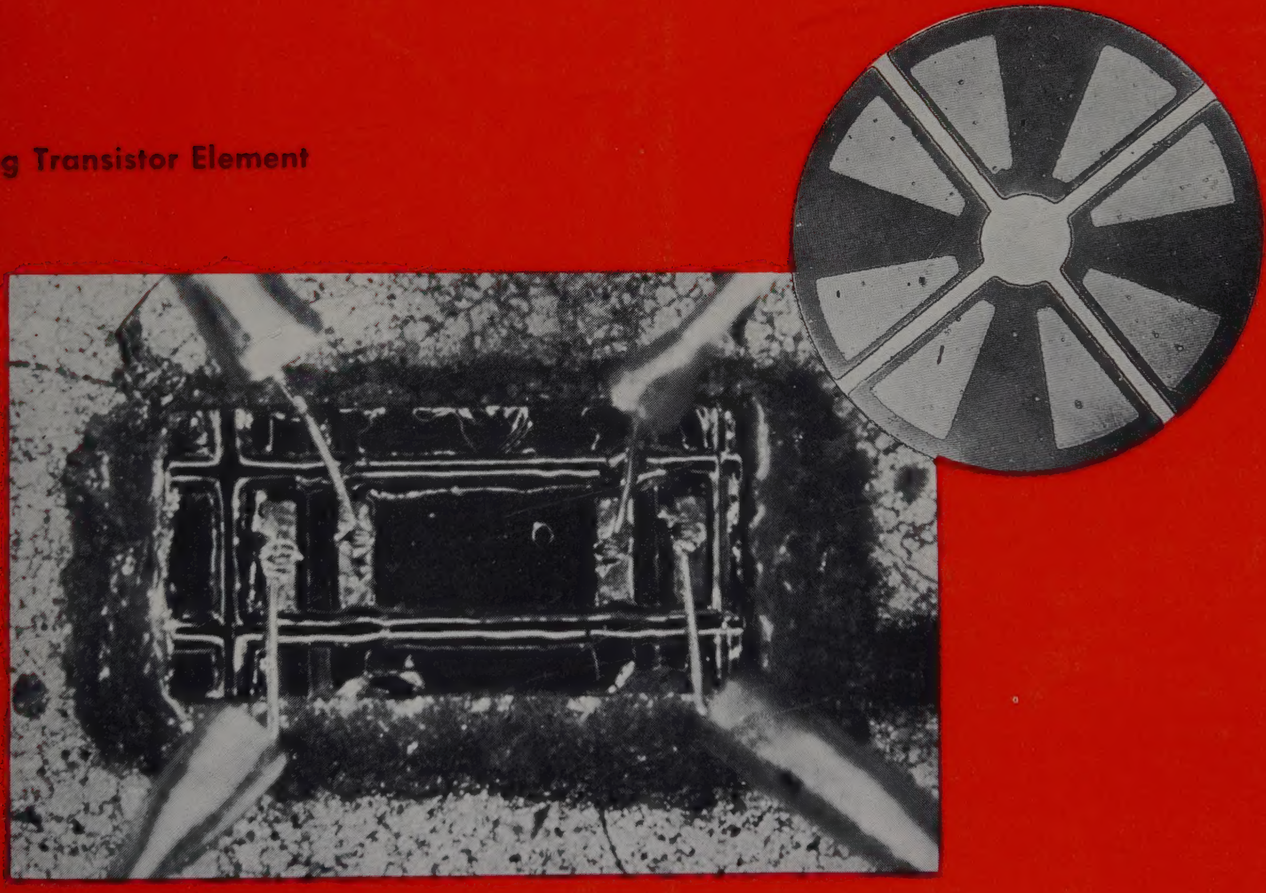
ping Transistor Element



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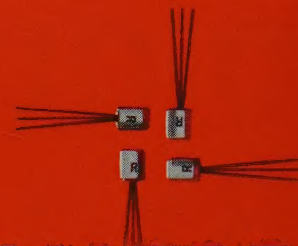
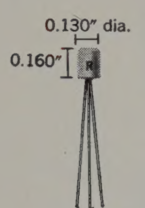


submin TRANSISTORS

SUBMIN PNP GERMANIUM TRANSISTORS of RAYTHEON RELIABILITY



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Temperature Range −65°C to +85°C

SUBMIN Type	JETEC-30 Electrical Equivalent	V_{CE} max. volts	$f_{\alpha b}$ ave. Mc	H_{FE_1} ave. $I_B = 1$ ma $V_{CE} = -0.25V$	H_{FE_2} ave. $I_B = 10$ ma $V_{CE} = -0.35V$	Rise Time* max. μsec
CK4	2N404	−24	12	30	—	—
CK25	2N425	−20	4	30	18	1.0
CK26	2N426	−18	6	40	24	0.55
CK27	2N427	−15	11	55	30	0.44
CK28	2N428	−12	17	80	40	0.33

*I_C — 50 ma; I_{B_1} = 5 ma; R_L = 200 Ω; I_{B_2} = 5 ma; Grounded Emitter Circuit

GENERAL PURPOSE AUDIO TRANSISTORS
Temperature Range −65°C to +85°C

SUBMIN Type	JETEC-30 Electrical Equivalent	V_{CE} max. volts	Beta ave. small signal	Power Gain Class A ave. db	I_{CO} ave. μa	Noise Factor ave. db
CK22	2N422	−20	90	40	6	6 max
CK64	2N464	−40	22	40	6	12
CK65	2N465	−30	45	42	6	12
CK66	2N466	−20	90	44	6	12
CK67	2N467	−15	180	45	6	12

GENERAL PURPOSE RADIO FREQUENCY TRANSISTORS
Temperature Range −65°C to +85°C

SUBMIN Type	JETEC-30 Electrical Equivalent	V_{CE} max. volts	$f_{\alpha b}$ ave. Mc	Beta ave.	Cob ave. μμf	rb″ ave. ohms
CK13	2N413	−18	2.5	25	12	70
CK14	2N414	−15	6	40	12	80
CK16	2N416	−12	10	60	12	90
CK17	2N417	−10	20	80	12	100

Dissipation Coefficients for all submin types: in air, 0.75°C/mW; infinite sink, 0.35°C/mW

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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

September 1959 Vol. 2 No. 9

Front Cover

"Stepping transistor element" developed at Bell Telephone Laboratories, mounted on a gold-plated Kovar header, is shown magnified about 50 times actual size. It may be used as a basic stage in constructing certain logic circuits of a digital computer. Leads are thermocompression bonded to gold-silver alloy contacts. Top view of stepping transistor structure (shown as insert) is fabricated on a single piece of silicon by oxide masking diffusion techniques. Actual diameter of the device is 40-thousandths of an inch. Light and dark areas show the different electrically-active regions of the stepping transistor structure. Lead wires are attached to the pie-shaped areas.

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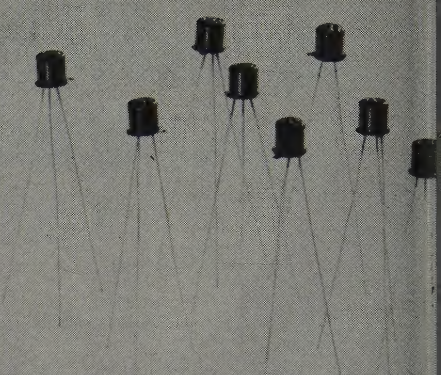


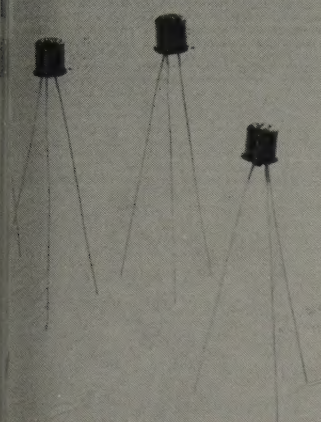
NEW FAIRCHILD 2N706 provides

TRANSISTOR LOGIC OF MAXIM

Saturating high-speed silicon logic ends the need to sacrifice one requirement in favor of another. The Fairchild 2N706 diffused silicon mesa transistor is as fast as the fastest germanium — and in addition has the inherent advantages of silicon. This combination fulfills all these logic-circuit design objectives:

SPEED	**10 megapulse operation saturated** **25 megapulse operation nonsaturated** **Guaranteed low storage**
RELIABILITY	**Large power reserve: 150 mW dissipation at 100° C ambient (no heat sink)** **300° C stabilization of all units** **Rugged mesa construction**
CIRCUIT SIMPLICITY	**Saturating logic with fewer components** **3 to 5 milliampere current level** **Small JEDEC TO-18 outline**

Fairchild's 2N706 provides optimum performance in the most-used logic circuit configurations and has a broad current and power range that covers many alternate approaches. It is ideally suited for high-density modular equipment because of its small size and its high performance in simple, low-power saturated circuits. The 10 megapulse speed is conservative, applying specifically to saturating logic and a 3 to 5 milliampere current level.



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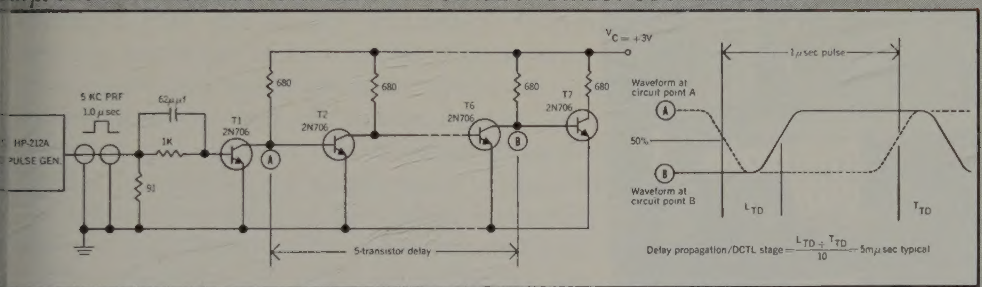
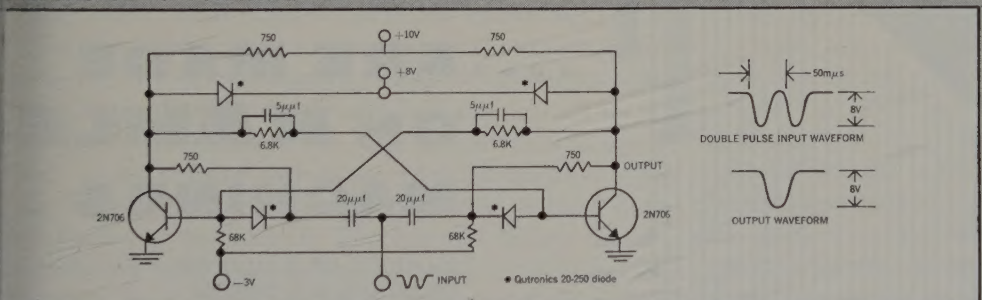


MEGACYCLE SATURATING FLIP-FLOP CIRCUIT



RATINGS AND CHARACTERISTICS (25° C) — 2N706 NPN DIFFUSED SILICON TRANSISTOR

Symbol	Characteristics	Rating	Min.	Typ.	Max.	Test Conditions	
V_{CBO}	Collector to base voltage	25 v					
V_{EBO}	Emitter to base voltage	3 v					
	Total dissipation, 100° C free air ambient	150 mw					
h_{FE}	D.C. pulse current gain		15			$I_C = 10mA$	$V_C = 10v$
$V_{BE(SAT)}$	Base saturation voltage				0.9	$I_C = 10mA$	$I_B = 1mA$
$V_{CE(SAT)}$	Collector saturation voltage			0.3	0.6	$I_C = 10mA$	$I_B = 1mA$
h_{fe}	Small signal current gain at f = 100 mc			4		$I_C = 20mA$	$V_C = 10v$
C_{ob}	Collector capacitance (140Kc)			3.5 pf	6 pf	$I_E = 0mA$	$V_C = 10v$

For specification sheets, write Dept.

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Editorial . . .

Low Temperature Avalanche Effects

As a result of the improvements in the techniques of liquefaction of helium, studies of low temperature phenomena in semiconductors have been greatly intensified. Although the novel devices proposed must compete with the devices which operate at room temperature, for convenience in practical application, the results nonetheless are of extreme interest.

A bulk avalanche effect in semiconductors at very low temperature was described recently by Sclar and Burstein (J.Phys.Chem.Solids Jan. 1957). At temperatures such that the thermal energy kT is less than the impurity activation energy in the semiconductor most carriers recombine with the impurities, and the remaining carriers acquire very large mobility. As a result, under the application of a small electric field (for example 10/ V/cm in germanium at 4.2°K) these free carriers may be accelerated sufficiently to produce avalanche ionization by inelastic collisions with the neutral impurities. Current rise times of the order of 10^{-9} sec have been observed in germanium and applications for the construction of switching diodes and of bistable devices have been proposed. (McWhorter and Rediker; Proc.IRE July 1959). The devices are simply built because they do not require *p-n* junction formation, but consist of a wafer of germanium with two ohmic contacts.

The possibility of pulse amplification has been pointed out by Steele, Pensak and Gold (Proc. IRE June 1959). This type of operation resembles somewhat the mechanism found in superregenerative amplifiers. The semiconductor wafer is provided with two terminal (ohmic) contacts and with a third intermediate ohmic contact. The unit is connected in series with a load resistor and driven with rectangular voltage pulses of amplitude large enough to produce bulk avalanche multiplication. The current builds up exponentially with time, but the overall current flowing through the load resistor depends on the distribution of potential along the semiconductor sample. By application of a short control pulse of polarity opposite to that of the drive pulse it is possible to enhance the value of the electric field in regions of the sample, obtaining as a result a larger integrated current. Peak power gains of the order of 20 have been obtained for pulses of durations 25 and 50 mμsecs.

Japanese Semiconductor Productivity

A subject of great importance to many semiconductor manufacturers today is the increasing productivity and future potential of the Japanese semiconductor industry. At present we in the industry, both producer and consumer, have not felt any significant effects of the Japanese industry because they have not really attempted to flood the American market with devices per se. They have mainly concentrated on the sale of completed equipment as evidenced by the sale of portable transistorized entertainment type receivers rather than the individual components. The cost of these end items are quite competitive with similar American products possibly because historically the Japanese have had this market in the East prior to the blossoming of our own demands.

Because of the sale of these receivers the Japanese device concentration has been in the germanium alloy junction transistor. However in the past year there has been a tendency for the Japenese transistor specifications to reflect more and more other applications, including switching. In addition there is no reason to believe that the Japanese will rest at this point. Instead, they seem to be going on to other devices and materials which may affect present industrial as well as future entertainment markets. It will be interesting to note the effect of the Japanese industry on American semiconductor production in the future, and what measures will be taken to combat a deluge of foreign devices on the market.

Growth of American Semiconductor Suppliers

The transistor industry had its birth a little over ten years ago, and with its inception new companies as well as new divisions of established electronic component suppliers were formed. During the middle era of this new industry the formation of additional companies dedicated to the manufacture of semiconductor devices was looked upon as a passing fancy. It was the opinion of the veterans of the time that as the industry "settled down" so would the number of manufacturers slowly revert to the Stalwarts of the electronic component suppliers and a very few independents.

With the past few months at least four new companies have announced their intentions of manufacturing and/or supplying semiconductor devices. This has come on the heels of the formation of many other manufacturers of semiconductor devices during the past two years. To those paying heed to the soothsayers of the industry who claim the number of companies will decrease as the industry settles down it would be well to point up the tendencies in the opposite direction and the further gains being made in the sale and application of semiconductors.

Samuel L. Marshall

POLYCRYSTALLINE SILICON SPECIFICATIONS

Grade	Resistivity P-Type	Max. Resistivity Ratio for 10% & 60% Points	Max. Boron Content (ppb)
IA	500	3:1	0.5
I	100	3:1	1.0
II	50	3:1	2.0
III	25	3:1	7.0
IV	2.5	3:1	—

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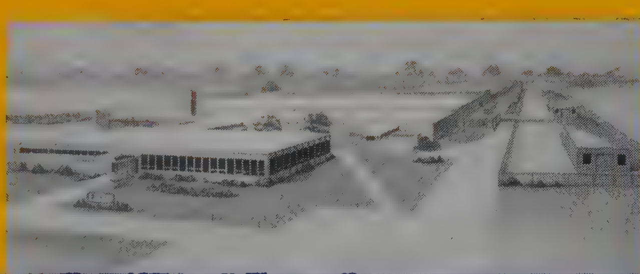

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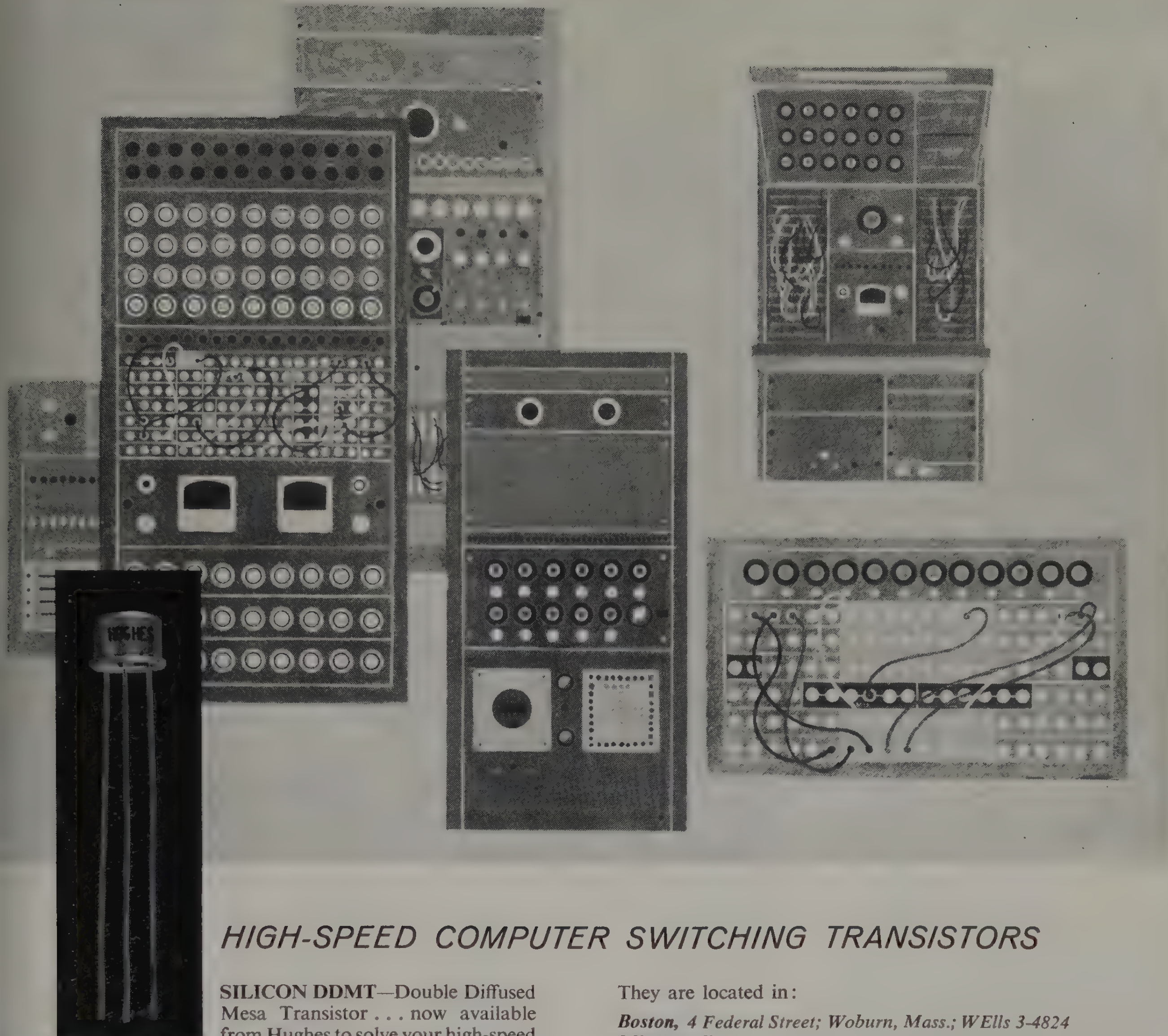

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Two other advantages: 1. This Hughes transistor offers you ll the desirable characteristics inherent in the solid state diffusion echnique. 2. The tiny flexible leads of its gold plated package may be soldered directly into circuits or used with standard plug-in sockets.

This new device, while designed primarily for computers, is also in excellent amplifier and oscillator, lending itself to an unusually broad range of applications.

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SPECIFICATIONS: Absolute Maximum Ratings (25°C)

	2N1254	2N1255	2N1256	2N1257	2N1258	2N1219
BV_{CEO}	15V	15V	30V	30V	50V	50V
BV_{CBO}	15V	15V	30V	30V	50V	50V
BV_{EBO}	5V	5V	5V	5V	50V	3V
Power Dissipation			250 mw			
Ambient Temperature			−65°C + 175°C			

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APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST No. 13

Preliminary Investigation of Transistorized Saturable-Core D-C to A-C Converters at Frequencies above 2 kc; Lansdale Tube Co., Lansdale, Pa.

This investigation was initiated in response to a request for a *d-c* to *a-c* converter capable of delivering 20 watts from a 12 volt source at an output frequency between 3 *kc* and 12 *kc*.

Circuits Tested

Two balanced push-pull circuits with grounded collectors were tested—a common emitter circuit, (*Fig. 13.1*), and a common collector circuit. A common base circuit was not tested because such a network does not permit the collector to be grounded. Grounding the collector is desirable in order to provide a non-insulated thermal conductance from the collector junction to the chassis, thereby permitting operation at higher power outputs and/or higher ambient temperatures. If desired, the load can be driven from secondary windings. A silicon diode bridge rectifier was employed to facilitate measurements of the output power.

Comments

(1) At the higher frequencies the ferrite core is preferable to the tape-wound core, since the core losses in the latter become excessive, being on the order of 6-7 watts per ounce of core with 2-mil thick orthonol tape when driven to saturation at 10 *kc*. At 5 *kc*, the losses are rated at approximately 2-3 watts per ounce. The core material in the tape-wound unit that was used weighed approximately 1.5 ounces. The ferrite core not only was much lighter, but its power loss per unit weight was also much less. At the lower frequencies, however, the wave forms observed were generally smoother for the tape-wound core than for the ferrite core. The reasons for this were not investigated, but it is quite likely that with the manual method of winding, the leakage reactance simply happened to be significantly greater in the one case than in the other.

(2) The power transistors, Philco 2N352 units, were selected because of their low cost. At the higher frequencies, the transformer voltage wave form was quite distorted from the characteristic saturable-core, square wave shape. It is believed that this distortion was due primarily to the limitations in the time response of the transistors, for when replaced by high-frequency transistors the distortion disappeared.

(3) To insure dependable starting without an initial negative base bias, it was decided from previous experience that the N_f/N_p ratio at different frequencies should be approximately 0.3. Other values of the turns ratio were tried when testing the general circuit behavior at different frequencies; however, measurements have not been made with the ratio as a controlled independent variable at constant N_p or constant frequency.

(4) A 0.3 turns ratio implies a 4-volt induced emf in the feedback during the

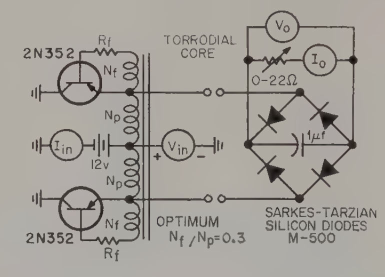

Fig. 13.1—DC to AC converter.

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"on" alternation of each cycle, so t additional resistance, R_f, was inser in each feedback circuit to reduce base current and hence the feedb power loss. The efficiencies at frequ cies above 12 *kc* were measured w R_f equal to 12 ohms, and below 12 with R_f equal to 6 ohms. Howev direct comparisons have not been m with R_f as an independent vari while the other circuit parameters held constant.

(5) For an ideal saturable-core h teresis loop and instantaneous switc ing time, the converter frequency given by the formula:

$$f = \frac{V_{in}}{4\,N_p\,\phi}, \quad \text{or} \quad f \cdot N_p = \text{constant}$$

where ϕ is the total flux at saturati and V_{in} is the *d-c* input supply volta applied across the transistor and N_p series. (The actual emitter-to-collec voltage across each transistor will va from approximately 0.1 or 0.2 volts du ing the "on" alternation to 2 V_{in} dur the "off" alternation of each cycl Under full load conditions the $f \cdot$ product did not remain a constant. T nonlinearity seemed primarily due the fact that the switching time of t transistors occupied a significant a frequency-variable portion of e cycle, rather than because of core regularities. Had the latter factor be the greater, the deviation of $f \cdot N_p$ wo have been approximately as large und no-load as under full-load operati but this was not observed. Further, t ragged wave forms, indicative of t prolonged switching action, were co verted into relatively smooth squa waves when the 2N352 units were r placed by *hf* transistors.

APPLICATIONS ENGINEERING DIGEST No. 14

Circuit Applications for Diffused Silicon Regulators, Texas Instruments Inc., Dallas, Texas.

Power regulator or Zener diodes have characteristics that are particularly well suited for shunt regulator applications. The current-voltage characteristic has a sharp break at approximately 0.1 ma. Beyond this point, the voltage across the diode remains almost constant for currents up to the maximum value obtained at the allowable power dissipation. The flat voltage characteristic is quite similar to a gas-tube regulator characteristic. The power regulator diode provides a wider choice of voltages and larger current ranges than do gas-tube regulators. In addition to these advantages, it does not require a firing voltage higher than the regulating voltage, as does a gas-tube regulator.

Shunt Regulated Power Supply

The power zener diodes provide a simpler means of obtaining a regulated *d-c* transistor bias supply. The advantage of this supply is the absence transformers and chokes, while fu nishing a regulated low voltage *d-c* w low ripple. (see *Fig. 14.1*)

The voltage provided at the 100 *m* capacitor by the bridge rectifier is 1 volts *d-c* with 11.5 volts peak to pe ripple. The resistor *R-2* and the fi regulator, 1N1829 provide additio filtering, reducing the ripple by a fact of 180, while reducing the voltage to

[*continued on page 16*]

RCA-2N1300 and 2N1301

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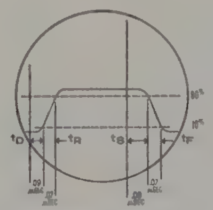
- high breakdown voltage and punch-through voltage ratings—the result of the diffusion process
- high power dissipation—150 milliwatts at 25°C—aids in the design of reliable circuits
- high current ratings—improve overall system speed
- rugged overall design—units have unusual capabilities to withstand severe drop tests and electrical overloads
- electrical uniformity—a result of the diffused-junction process used by RCA in the manufacture of Mesa Transistors
- especially well suited for use at pulse repetition rates up to 20 Mc
- exceptionally well suited to applications in saturation-type switching circuits

Information on RCA-2N1300 and 2N1301 Low-Cost Mesa Transistors is available from your RCA Field Representative. For technical data, write RCA Commercial Engineering, Section 1-100-NN, Somerville, N.J.

RCA TYPE	Maximum Ratings▲ Absolute-Maximum Values						Characteristics: Common-Emitter Circuit, Base Input Ambient Temperature of 25° C		
	Collector-to-Base Volts	Emitter-to-Base Volts	Collector Milliamperes	Transistor Dissipation—mw			Minimum DC Current Gain		Gain Bandwidth Product● Mc
				at 25°C	at 55°C	at 71°C	at collector ma = −10	at collector ma = −40	
2N1300	−13	−1	−100	150	75	35	30	—	40
2N1301	−13	−4	−100	150	75	35	30	40	60

▲Maximum collector-to-emitter voltage rating = −12 volts

● For collector ma = −10 and collector-to-emitter volts = −3.



Oscilloscope wave form shows typical delay, rise, storage, and fall times achieved with 10-ma inverter circuit utilizing the RCA-2N1301 MESA TRANSISTOR.

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volts. The value of the series resistor, R_{-2}, was calculated to allow a current of approximately 50 *ma* to pass through the first diode, at a nominal input of 120 volts *rms.*

The second regulator provides further ripple reduction, (a factor of 16 at full load) and regulates the output voltage for load variations from 0 to 150 *ma.* The output voltage drops about 2% when the load is changed from 0 to 150 *ma,* giving an output resistance of approximately 3.3 ohms.

The circuit will take input fluctuations from 100 to 140 volts with little effect on the output. If lower voltages are expected, the circuit may be designed so that the 1N1829 will carry a larger current at 115 volts. The upper limit is imposed by the rating of the 1N1829.

Transistor Surge Protectors

The power handling capabilities of the 1N1821 series make them particularly well suited for surge protection of expensive power transistors. A complete voltage range of diodes available makes it possible to protect transistors of almost every collector voltage rating. The regulator diode breakdown voltage should be chosen just below the transistor zener voltage so that it will shunt surge peaks, but not interfere with normal operation.

A typical surge protection application of the power regulator diodes is illustrated in *Fig. 14.2.* The two 2N457 germanium power transistors used in the converter have a maximum voltage rating of 60 volts. These transistors are protected from punch-through by the 56 volt 1N1831 regulators which shunt surge peaks, but do not interfere with normal operation of the circuit. The double anode feature of these diodes make them applicable to the protection of either *p-n-p* or *n-p-n* transistors, without having to be insulated from the heat sink.

Arc Suppression

The ability of power zener diodes to handle high surges may be applied in arc suppression. The high non-recurrent peak rating allows the diodes to dissipate surge power which would otherwise cause contact arcing and deterioration, insulation breakdown, and wide-band electrical interference.

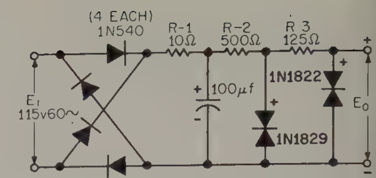

Fig. 14.1—Shunt regulation.

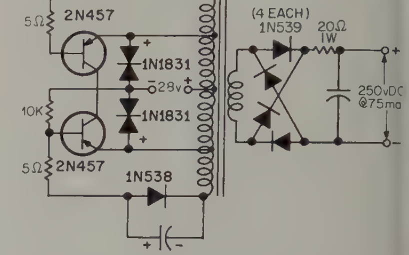

Fig. 14.2—Surge protection circuit.

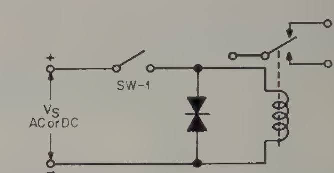

Fig. 14.3—Arc suppression by surge limiting.

A surge suppression application of the double anode clipper diode is shown in *Fig. 14.3* The double anode feature permits the diode to be used in either *a-c* or *d-c* inductive circuits. The diode used in this application should have a "Zener" voltage slightly greater than the peak supply voltage, V_s. This allows normal operation of the relay circuit when the switch (*SW-1*) is closed. The instant the switch is opened the inductance causes a high voltage surge. As the surge voltage reaches the diode breakdown voltage, the diode resistance drops to a very low value, and thus suppresses contact arcing by limiting the peak surge voltage.

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APPLICATIONS ENGINEERING DIGEST No. 15

Application of High Frequency "y" Parameters, Fairchild Semiconductor Corp., Palo Alto, Calif. (G. Reddi)

As the use of transistors in *r-f* amplification is ever increasing, it is essential for a designer to understand the small-signal properties of the transistors at those frequencies. For this purpose, the functional model of a transistor can be considered as a linear active two-port network, which can be specified at a particular frequency by a set of four independent parameters. These parameters completely characterize the device for power gain considerations. In transistor work the most commonly used parameters are the "*y*" (shore circuit admittances) and the "*h*" (hybrid) parameters. Each of these sets involves two immittances measured at the input and output terminal pairs (the opposite terminal pair being either open or short-circuited), and two transfer parameters.

In this memorandum the *y* parameter representation of linear two-port devices and the measurement of transistor *y* parameters at high frequencies are discussed. Different ways of designing

[continued on page 17]

single stage transistor amplifiers using small-signal two-port parameters are indicated. The usefulness of y parameters in the investigation of the potential instability and the calculation of maximum available power gain of a transistor is demonstrated. A numerical example is worked out using y parameters in amplifier circuit design.

Measurement of Transistor "y" Parameters at High Frequencies

The short-circuit measurements indicated in the various definitions of the y parameters can be readily made, using simple bridge techniques. A three-terminal device like a transistor triode can be connected in three different ways—namely common base, common emitter and common collector. Associated with these three orientations there are six driving points and three transfer admittances that can be measured, but measurement of certain combinations of four admittances out of the above nine will be sufficient to characterize the transistor in any orientation. The choice of the four parameters to be measured depends on the ease of measurement, accuracy desired, usefulness of direct reading type of measuring equipment available, etc. The Wayne Kerr B801 VHF Admittance Bridge (range 1mc-100mc), which is one of the well-suited instruments for y parameter measurements, is being used for this work. The parameters being measured are y_{11e}, y_{22e}, y_{12e} and y_{11b}. (The subscripts "b" and "e" refer to grounded base and grounded emitter configurations respectively).

Simplified diagrams of the Wayne Kerr B801 bridge and the circuits to measure the above-mentioned four y parameters are shown in *Figs. 15.1* and *15.2*. It should be noted that the neutral terminal N is left open when driving

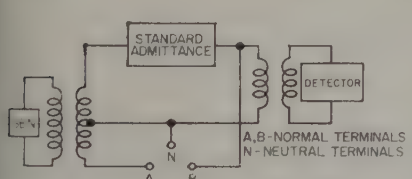

Fig. 15.1—Simplified diagram of the Wayne-Kerr B801 Bridge.

point admittances are measured. The values of capacitances in the above-shown circuits are chosen such that they offer a good short circuit at the frequency of measurement.

Design of Single Stage Narrow Band Transistor R.F. Amplifier Using y Parameters

The transducer gain, defined as the ratio of actual load power to the power available from the source when the transistor is neutralized, can be calculated by the relation:

$$G_{T\ neutralized} = \frac{4\,[y_{21} - y_{12}]^2\, g_s\, g_L}{[(y_s + y_{11} + y_{12})(y_L + y_{22} + y_{12})]^2}$$

If the source and load admittances provide conjugate matches after neutraliza-

[continued on page 62]

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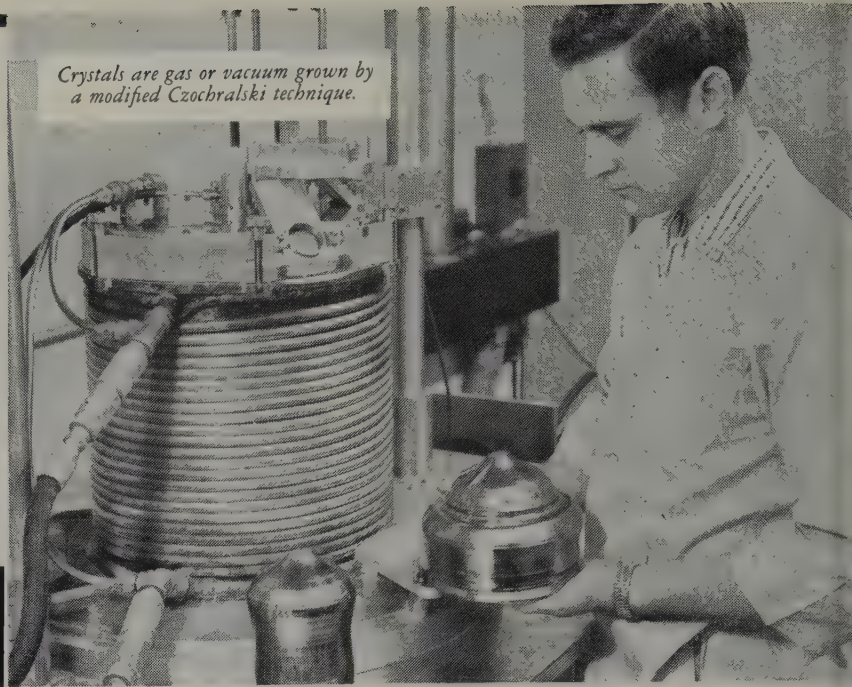

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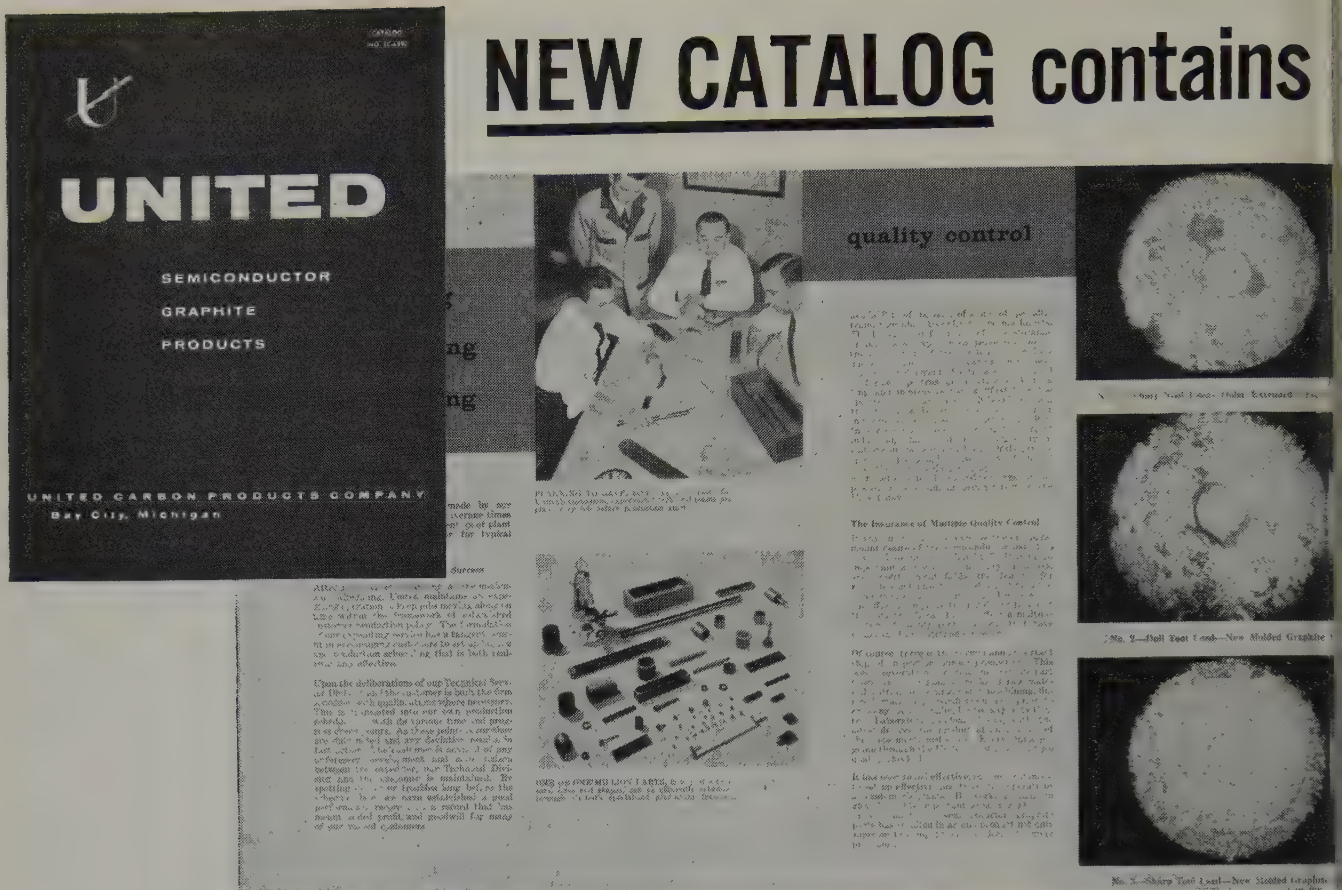

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Crystal Controlled High Frequency Transistor Oscillators

W. F. CHOW*

Crystal controlled transistor oscillators of 10-50 *mc* frequency range were studied for their frequency stability with change of supply voltage and of temperature. Good frequency stability can be obtained from a properly designed transistor oscillator without the use of non-linear compensation techniques or the need for any temperature controlled chamber. Experimental results give a frequency change of 3.9 parts per million per 10% change of supply voltage, and a frequency change of only 0.22 part per million per degree centigrade of ambient temperature change.

[Tear sheets of this article are available on written request]

CRYSTAL CONTROLLED OSCILLATORS are used very often in communication equipments. Whether used as the master oscillator of a transmitter or as the local oscillator of a receiver, one of the essential functions of a crystal controlled oscillator is to produce a frequency of oscillation which is stable with changes of supply voltage and of ambient temperature. The oscillator circuit should be such that the frequency of oscillation is determined by the crystal only. Any change of the frequency with temperature should be contributed by the crystal, and if possible, other circuit elements should react to the change of temperature in such a way that the frequency change is compensated.

In vacuum tube circuitry, the above requirements of crystal controlled oscillation are met partly by circuits such as the Pierce, Miller, bridged T, Butler cathode coupled, transformer coupled oscillators, etc. The simplified circuit diagrams of these oscillators are shown in *Figs. 1* to *5*. Each circuit has its own limitations and a certain field of application. With a good quality crystal, a frequency stability of about ±0.0015% against the change of temperature from −60°C to +100°C can be achieved.

Since the properties of a transistor differ from those of a vacuum tube, it is often found that a transistor crystal controlled oscillator derived from a tube circuit does not give the stability desired. It is also found that some transistor circuits are not able to oscillate at the harmonic frequency of a crystal, especially in the *vhf* region. This article presents the results of a study of crystal controlled transistor oscillators, and the development of a new crystal controlled transistor oscillator.

Review of Some Commonly Used Crystal Controlled Transistor Oscillators

There are several commonly used crystal controlled transistor oscillators as shown in *Figs. 6* to *9*. The prin-

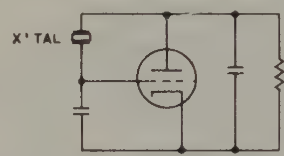

Fig. 1—Pierce oscillator

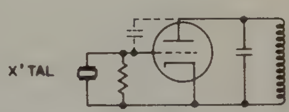

Fig. 2—Miller oscillator

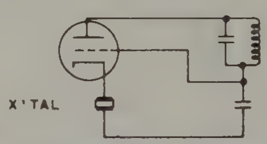

Fig. 3—Bridged T oscillator

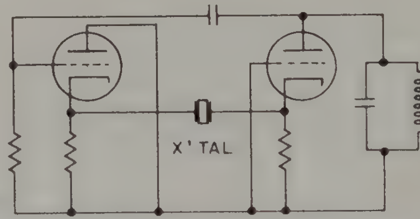

Fig. 4—Butler cathode coupled oscillator

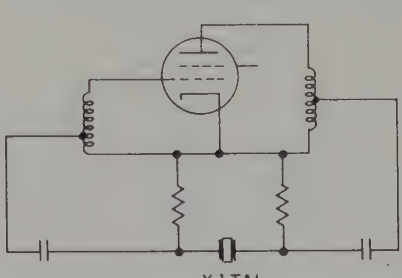

Fig. 5—Transformer coupled oscillator

*General Electric Company, Syracuse, N. Y.

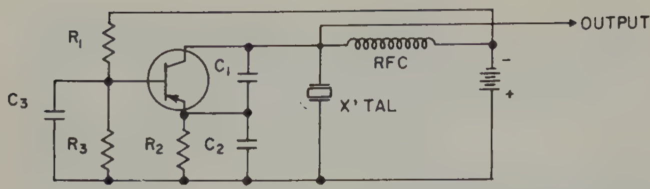

Fig. 6—Commonly used transistor oscillator No. 1

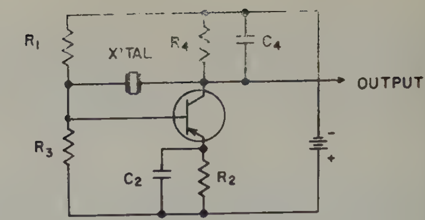

Fig. 7—Commonly used transistor oscillator No. 2

ciples of oscillation of these circuits can be visualized as follows:

(1) *Fig. 6* shows a Clapp oscillator. Resistors R_1 and R_3 provide proper base bias. C_3 is an *rf* by-pass capacitor. R_2 provides the emitter *d-c* path. C_1 and C_2 form a feedback circuit. The *rfc* is used in the collector bias voltage path. A resistance may be used in its place and is occasionally found to be better than the *rfc* as protection against spurious oscillations.

The crystal is operated at frequencies between its series resonant frequency and its parallel resonant frequency. Thus, a simplified *a-c* equivalent circuit of the Clapp oscillator is shown in *Fig. 10(a)* and *10(b)*. The electrical characteristics of the crystal are represented by the series parallel network of C_p, C_s, r and L, as shown in *Fig. 10(a)*. For frequencies between the series resonant frequency and the parallel resonant frequency, the network reduces to the one shown in *Fig. 10(b)* where

$$r' = \frac{1}{\left[\dfrac{r}{r^2 + \left(\omega L - \dfrac{1}{\omega C_s}\right)^2}\right]} \quad (1)$$

and

$$\omega L_e = \frac{1}{\left[\dfrac{\left(\omega L - \dfrac{1}{\omega C_s}\right)}{r^2 + \left(\omega L - \dfrac{1}{\omega C_s}\right)^2} - \omega C_P\right]} \quad (2)$$

The equivalent circuit shown in *Fig. 10(b)* is the same as the familiar Colpitts oscillator. Therefore, the principle of oscillation is the same. Capacitor C_2 is usually one or two orders of magnitude larger than C_1, and capacitor C_1 is usually one or two orders of magnitude larger than the collector to base junction capacitance of the transistor.

At 1 *mc*, a frequency stability of ± 2 *ppm* for $\pm 10\%$ supply voltage variation and 120 *ppm* for a temperature change of $-50°C$ to $+80°C$ can be achieved. This circuit is, however, less able to oscillate at higher frequencies. This is due to the phase shift between the emitter and the collector junctions. The feedback signal provided by capacitors C_1 and C_2 becomes out of phase as the frequency increases.

(2) *Fig. 7* shows a circuit similar to the Pierce oscillator shown in *Fig. 1*. Resistances R_1, R_3 and R_2 provide the *d-c* bias for the base and the emitter. C_2 is an *rf* by-pass capacitor. Resistance R_4 provides the collector *d-c* path and it also appears as part of the load, if small. Capacitance C_4 is used to obtain the proper phase relation.

The principle of oscillation of this circuit can be visualized in the simplified *a-c* circuits shown in *Figs. 11(a)* and *11(b)*. The crystal is used at a frequency between its series resonant frequency and its parallel resonant frequency, and therefore it acts as an inductance. In *Fig. 11(b)*, L_e is the equivalent effective inductance of the crystal. The position of L_e in the circuit is rearranged. The connection of inductance L_e to the base is marked "a," and is indicated by the dotted line. This rearrangement of circuit components makes it clear that the oscillation is produced by the feedback of the amplified signal into the base through the tank circuit L_e-C_4, and the output capacitance of the transistor. With the feedback connection "a-a" open, the circuit shown in *Fig. 11(b)* can be easily recognized as a common

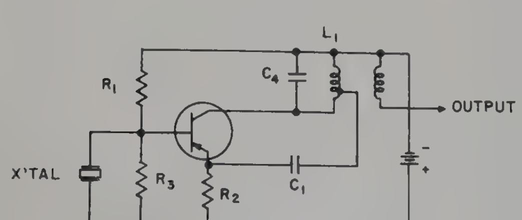

Fig. 8—Commonly used transistor oscillator No. 3

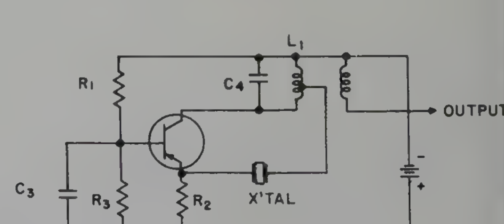

Fig. 9—Commonly used transistor oscillator No. 4

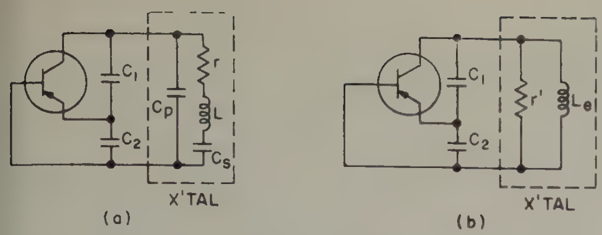

Fig. 10—Equivalent circuit of Fig. 6

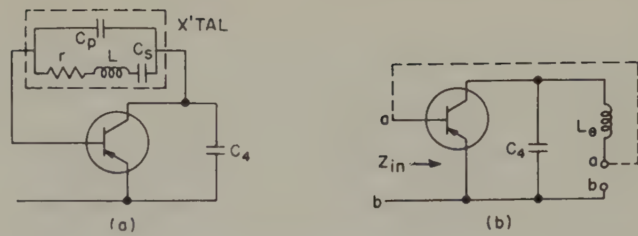

Fig. 11—Equivalent circuit of Fig. 7

emitter *rf* amplifier. The signal fed into the base terminal is amplified and the output is fed to the load at one end of the inductance L_e. Therefore the ability of this oscillator to oscillate at high frequencies is determined by the power gain of the common emitter circuit at high frequencies, and proper impedance transformation of the tank circuit.

(3) *Fig. 8* shows an oscillator having the crystal in the base circuit. Resistors R_1 and R_3 provide the base bias. R_2 provides the emitter *d-c* path. The feedback circuit consists of a tap on the inductance L_1 and capacitance C_1. The crystal is operated in the series resonant mode. The amount of feedback through capacitance C_1 to the emitter is adjusted to such a small value that oscillation begins only when the crystal is series resonant. Thus, the simplified *a-c* equivalent circuits are as shown in *Figs. 12* (*a*) and *12* (*b*). Since the loss resistance r of a crystal is usually very small, the circuit shown in *Fig. 12* (*b*) is similar to the well-known Hartley oscillator. The control of the amount of feedback is accomplished through proper tapping of inductance L_1. Capacitance C_1 blocks the collector bias voltage and is also used to obtain a certain amount of phase shift necessary to compensate for the internal phase shift of the transistor. Therefore, this circuit oscillates more readily at higher frequencies than the one shown in *Fig. 6*.

However, the frequency stability of this circuit is relatively poor. As the frequency increases, the reactance of the stray circuit capacitance across the crystal and the C_p of the crystal, becomes smaller. This circuit may oscillate at frequencies other than that of the crystal frequency.

(4) *Fig. 9* shows a circuit similar to the one in *Fig. 8* but having the crystal inserted in the feedback path, and the base by-passed to the ground by a capacitance C_3. The crystal is again operated in its series resonant mode. Simplified *a-c* circuits are shown in *Figs. 13* (*a*) and *13* (*b*). The frequency stability is also relatively poor. The tapping point of the feedback path is critical for good frequency stability. As the frequency increases, the reactance of the stray capacitance and the C_p of the crystal, becomes smaller. This circuit may also oscillate at frequencies other than that of the crystal frequency.

A New Crystal Controlled High Frequency Transistor Oscillator

Figure 14 shows a new crystal controlled transistor oscillator. Resistances R_1, R_2 and R_3 provide the *d-c* bias for the base and the emitter. The load is connected to the secondary winding of the transformer *T*. Proper impedance transformation is provided by the transformer to step up the impedance of the load to the level of the primary winding.

The crystal is used at a frequency between its series resonant frequency and its parallel resonant frequency. Therefore, it appears as an inductance. Resistances R_1, R_2 and R_3 are large and their *a-c* effects can be neglected. *Figs. 15* (*a*) and *15* (*b*) show the simplified equivalent circuits of the oscillator. In *Fig. 15* (*b*), L_e is the equivalent inductance given by Eq. (2). The equivalent loss resistance r' given by Eq. (1) is usually very large and is neglected here. R_L is the equivalent load resistance.

Using a simplified "T" equivalent circuit for the transistor as shown in *Fig. 16*, this oscillator can be analyzed as follows:

In *Fig. 15* (*b*), the input impedance of the transistor at points "1-2" is

$$Z_{in} = h_{11} - \frac{h_{12}\, h_{21}}{h_{22} + Y_L} \qquad (3)$$

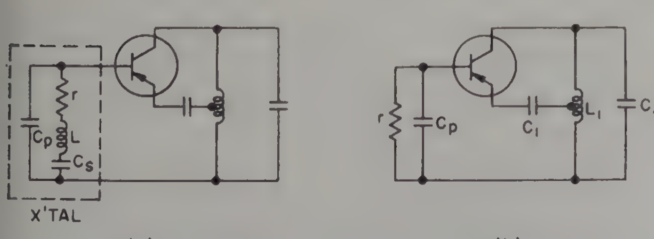

Fig. 12—Equivalent circuit of Fig. 8

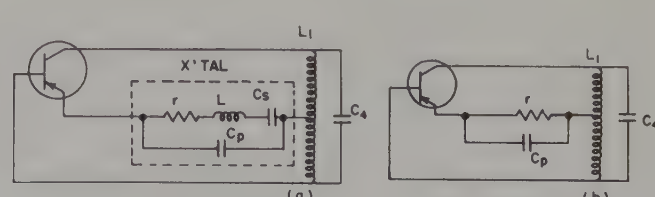

Fig. 13—Equivalent circuit of Fig. 9

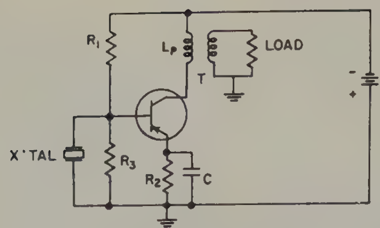

Fig. 14—A new crystal controlled high frequency transistor oscillator.

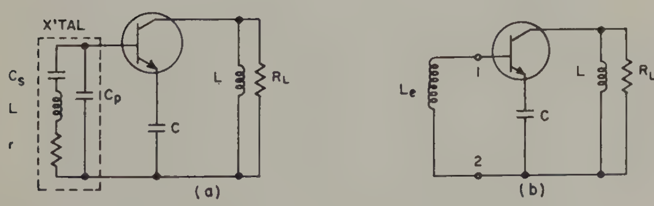

Fig. 15—Equivalent circuit of Fig. 14

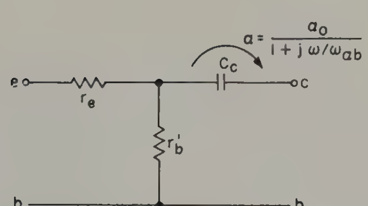

Fig. 16—Simplified transistor equivalent circuit

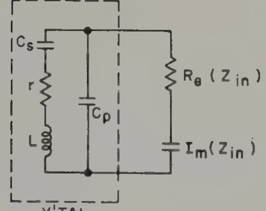

Fig. 17—Simplified equivalent circuit of Fig. 14

TABLE I

TRANSISTOR NO.	CRYSTAL FREQUENCY (PARALLEL RESONANT)	Δf	CRYSTAL FREQUENCY (SERIES RESONANT)	Δf	CRYSTAL FREQUENCY (PARALLEL RESONANT)	Δf
	27140.000 KC	CPS	33208.000 KC	CPS	46660.000 KC	CPS
1	27138.733	1267	33209.774	1774	46654.105	5895
2	27139.274	726	33210.395	2395	46655.127	4873
3	27138.745	1255	33209.796	1796	46654.492	5508
4	27138.745	1255	33209.690	1690	46654.279	5721
5	27138.846	1154	33209.881	1881	46654.715	5285
6	27139.142	858	33210.312	2312	46655.052	4948
7	27139.080	920	33210.224	2224	46654.895	5105
8	27138.721	1279	33209.703	1703	46654.022	5978

where

$$Y_L = \frac{1}{R_L} + \frac{1}{j\omega L} \qquad (4$$

and h's are the two port h parameters of the transistor having a capacitor C in the emitter lead.

Since the input impedance Z_{in} is directly across the crystal, this oscillator circuit can be simplified further as shown in *Fig. 17*, where $R_e(Z_{in})$ and $I_m(Z_{in})$ are the real and imaginary components respectively. The conditions required to produce oscillation are that the real part of the input impedance must be negative and the loss of the crystal be small. The condition required to exclude the possibility of spurious oscillation is that the imaginary component of the input impedance must be capacitive. These conditions can be met by a proper design of the ratio $\frac{C}{C_c}$ as derived in the appendix. Thus $\frac{C}{C_c}$ should be within the boundaries set by two values obtained from Eq. (21).

$$\frac{C}{C_c} = \frac{(\omega_{ab}/\omega)^2}{2\omega_{ab}\, C_c\, r_b'} - 1 \pm \sqrt{\left[\frac{(\omega_{ab}/\omega)^2}{2\omega_{ab}\, C_c\, r_b'} - 1\right]^2 - \left(\frac{\omega_{ab}}{\omega}\right)^2 - 1}$$

For example, let

$$\frac{1}{\omega_{ab}\, r_b'\, C_c} = 3, \text{ and } \frac{\omega_{ab}}{\omega} = 2$$

The ratio $\frac{C}{C_c}$ should be $0.53 < \frac{C}{C_c} < 9.47$ and the negative resistance reaches a maximum when $\frac{C}{C_c} =$ 0.9. In order to insure a strong oscillation, the ratio of $\frac{C}{C_c}$ should be about 0.9.

The equivalent capacitance of the input impedance is given by Equation (22) derived in the Appendix.

$$C_e = C_c \frac{1 + \left(\frac{\omega}{\omega_{ab}}\right)^2 \left(1 + \frac{C}{C_c}\right)^2}{1 + \left(\frac{\omega}{\omega_{ab}}\right)^2 \left(1 + \frac{C}{C_c}\right)} \qquad (22)$$

For the above example $C_e \cong 1.29\ C_c$. The frequency of oscillation is determined by the C_e of the input impedance and L_e of the crystal.

Experimental Study of the New Oscillator

The circuit used in the test is shown in *Fig. 18*. Eight G. E. germanium tetrodes 3N37 were used in the test. The bias point of the tetrodes was fixed at an emitter current $I_e = 1.8\ ma$, interbase bias $V_{bb} = -4$ V, and collector bias voltage $V_c = 6$ V.

Test (A). Three crystals were used to test the frequency deviation among transistors at room temperature and fixed bias supplies. The results are shown in Table I.

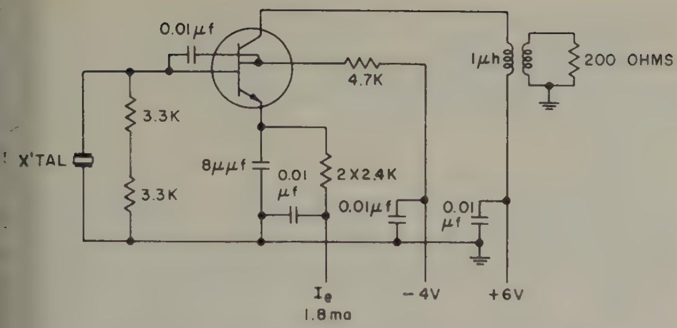

Fig. 18—Experimental oscillator circuit

At 27140.000 *kc* crystal frequency, the average deviation of the actual frequency from the crystal frequency is 0.004%. The average deviation of the actual frequency from the average of the actual frequency 27138.914 *kc* is 0.00053%.

At 33208.000 *kc* crystal frequency, the average deviation of the actual frequency from the crystal frequency is 0.0059%. The average deviation of the actual frequency from the average of the actual frequency 33209.971 *kc* is 0.00076%.

At 46660.000 *kc* crystal frequency, the average deviation of the actual frequency from the crystal frequency is 0.0116%. The average deviation of the actual frequency from the average of the actual frequency 46654.588 *kc* is 0.00078%.

Test (B). At room temperature, the frequency deviation due to the change of supply voltage was measured. The results are plotted in *Fig. 19.* A frequency change of 3.9 parts per million for a 10% change of supply voltage was found.

Test (C). The circuit shown in *Fig. 18* was used in the temperature test. The bias supply voltage was kept constant. Both the crystal and the transistor were subjected to the variation of temperature. The results were plotted in *Fig. 20.* A typical *"S"* curve was found. For the temperature range of −30°C to +70°C the maximum frequency change was within 0.00096%. The temperature characteristic curve of the crystal used in the test is shown in *Fig. 21.*

Discussion

During the experimental study it was found that the value of capacitor C in *Fig. 14* determined the range of frequency within which the circuit oscillated. A given crystal can be used and the circuit can be made to oscillate either at the fundamental frequency or at its odd harmonics simply by changing the capacitance C from a large value to a small value. This phenomenon is also indicated in *Eq. 16* of the Appendix, which shows that the negative resistance is a function of $\frac{C}{C_c}$ and $\frac{\omega}{\omega_{ab}}$.

Since inductance L_p in *Fig. 14* was not tuned to resonate at the frequency of oscillation, and since it was also heavily loaded to give a poor Q, the change in frequency of oscillation was accomplished by changing only the crystal without any change or readjustment of circuit components. It was also found that if the oscillation was strong, harmonics of good

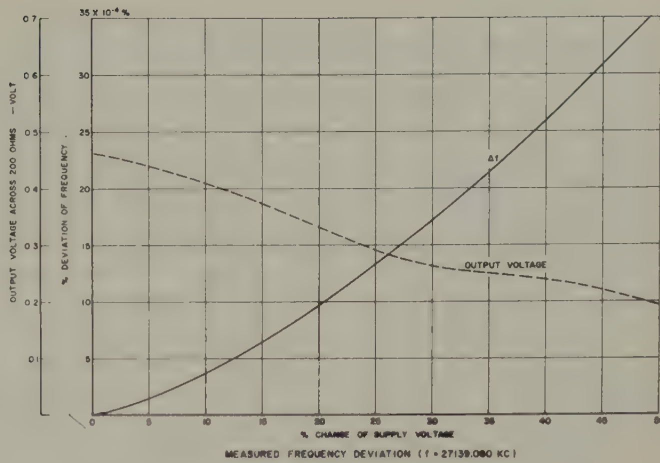

Fig. 19—Measured frequency deviation (f = 27139.080 *kc*)

Fig. 20—Temperature characteristic of the oscillator

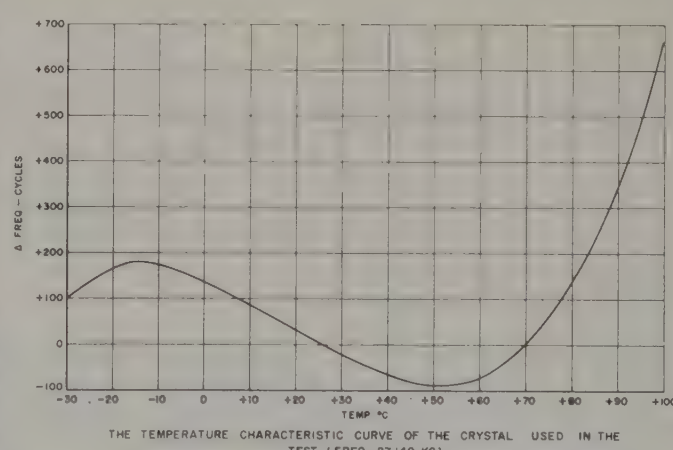

Fig. 21—Temperature characteristic curve of the crystal used in the test (Freq.-27,140. *kc*)

amplitude could be obtained by tuning L_p with a capacitance to the harmonic frequency. Thus, a frequency multiplying stage is not necessary for frequencies such as 150 or 200 *mc*, etc.

The experimental data show that the frequency stability of this new oscillator, shown in *Fig. 14*, is better than the other crystal controlled transistor oscillators discussed previously, and is also found to be better than that of most vacuum-tube circuits.

Acknowledgement

The author wishes to thank C. D. Aiken for hi[s] assistance in making the measurements.

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APPENDIX

The h parameters of a common emitter transistor having a capacitor C in the emitter lead are:

$$h_{11} = \frac{\left(r_e + \frac{1}{j\omega\, C}\right) r_b' + \frac{1}{j\omega\, C_c}\left[\left(r_e + \frac{1}{j\omega\, C}\right) + r_b'\,(1-\alpha)\right]}{\left(r_e + \frac{1}{j\omega\, C}\right) + \frac{1}{j\omega\, C_c}\,(1-\alpha)} \tag{5}$$

$$h_{12} = \frac{r_e + \frac{1}{j\omega\, C}}{\left(r_e + \frac{1}{j\omega\, C}\right) + \frac{1}{j\omega\, C_c}\,(1-\alpha)} \tag{6}$$

$$h_{21} = \frac{-\left(r_e + \frac{1}{j\omega\, C} - \frac{\alpha}{j\omega\, C_e}\right)}{\left(r_e + \frac{1}{j\omega\, C}\right) + \frac{1}{j\omega\, C_c}\,(1-\alpha)} \tag{7}$$

$$h_{22} = \frac{1}{\left(r_e + \frac{1}{j\omega\, C}\right) + \frac{1}{j\omega\, C_c}\,(1-\alpha)} \tag{8}$$

In a practical circuit $\left|\frac{1}{j\omega\, C}\right| \gg r_e$. Therefore

$$h_{11} \cong \frac{\frac{r_b'}{j\omega\, C} + \frac{1}{j\omega\, C_c}\left[\frac{1}{j\omega\, C} + r_b'\,(1-\alpha)\right]}{1/j\omega\, C + \frac{(1-\alpha)}{j\omega\, C_c}}$$

$$\cong \frac{r_b' + \frac{C}{C_c}\left[\frac{1}{j\omega\, C} + r_b'\,(1-\alpha)\right]}{1 + \frac{C}{C_c}\,(1-\alpha)} \tag{9}$$

and

$$\frac{h_{12}h_{21}}{h_{22} + Y_L} \cong \frac{-\left(\frac{1}{j\omega\, C} - \frac{\alpha}{j\omega\, C_c}\right)}{1 + (1-\alpha)\,\frac{C}{C_c} + j\omega\, C Y_L\left[\frac{1}{j\omega\, C} + \frac{1-\alpha}{j\omega\, C_c}\right]^2} \tag{10}$$

Using the relations:

$$\alpha = \frac{\alpha_0}{1 + j\,\omega/\omega_{ab}} \tag{11}$$

$$(1-\alpha_0) \ll \frac{\omega}{\omega_{ab}} \tag{12}$$

and

$$\frac{C}{C_c}\,(1-\alpha_0) \ll 1 \tag{13}$$

The real component of the input impedance Z_{in} is

$$R_e(Z_{in}) = r_b' - \frac{\dfrac{C}{C_c}\,\dfrac{1}{\omega_{ab}\,C_c}}{1 + \left[\dfrac{\omega}{\omega_{ab}}\left(1 + \dfrac{C}{C_c}\right)\right]^2} + R_e\left[\frac{h_{12}\,h_{21}}{h_{22} + Y_L}\right] \tag{14}$$

where $R_e\left[\dfrac{h_{12}\,h_{21}}{h_{22} + Y_L}\right]$ is the real part of the term $\dfrac{h_{12}\,h_{21}}{h_{22} + Y_L}$.

The imaginary component of Z_{in} is

$$I_m\,(Z_{in}) = j\,\frac{-\dfrac{1}{\omega C_c} - \dfrac{\omega}{\omega_{ab}}\left(1 + \dfrac{C}{C_c}\right)\dfrac{1}{\omega_{ab}\,C_c}}{1 + \left[\dfrac{\omega}{\omega_{ab}}\left(1 + \dfrac{C}{C_c}\right)\right]^2} + I_m\left[\frac{h_{12}\,h_{21}}{h_{22} + Y_L}\right] \tag{15}$$

Where $I_m\left[\dfrac{h_{12}\,h_{21}}{h_{22} + Y_L}\right]$ is the imaginary part of the term $\dfrac{h_{12}\,h_{21}}{h_{22} + Y_L}$.

If Y_L is large and the term $\dfrac{h_{12}\,h_{21}}{h_{22} + Y_L}$ can be neglected, then, as the first approximation,

$$R_e(Z_{in}) \cong r_b' - \frac{\dfrac{C}{C_c}\,\dfrac{1}{\omega_{ab}\,C_c}}{1 + \left[\dfrac{\omega}{\omega_{ab}}\left(1 + \dfrac{C}{C_c}\right)\right]^2} \tag{16}$$

and

$$I_m(Z_{in}) \cong j\,\frac{-\dfrac{1}{\omega\,C_c} - \dfrac{\omega}{\omega_{ab}}\left(1 + \dfrac{C}{C_c}\right)\dfrac{1}{\omega_{ab}\,C_c}}{1 + \left[\dfrac{\omega}{\omega_{ab}}\left(1 + \dfrac{C}{C_c}\right)\right]^2} \tag{17}$$

Since this input impedance Z_{in} is directly across the crystal as shown in *Fig. 17* a negative resistance must exist in order to produce oscillation. Thus, from Equation (16)

$$\frac{C}{C_c}\,\frac{1}{\omega_{ab}\,C_c} \geqslant r_b'\left[1 + \left(\frac{\omega}{\omega_{ab}}\right)^2\left(1 + \frac{C}{C_c}\right)^2\right] \tag{18}$$

In order to find the range of $\dfrac{C}{C_c}$ with which the negative resistance exists we set

$$\frac{C}{C_c}\,\frac{1}{\omega_{ab}\,C_c} = r_b'\left[1 + \left(\frac{\omega}{\omega_{ab}}\right)^2\left(1 + \frac{C}{C_c}\right)^2\right] \tag{19}$$

or

$$\left(\frac{C}{C_c}\right)^2 + \left[2 - \frac{(\omega_{ab}/\omega)^2}{\omega_{ab}\,C_c\,r_b'}\right]\left(\frac{C}{C_c}\right) + \left(\frac{\omega_{ab}}{\omega}\right)^2 + 1 = 0 \tag{20}$$

solving for $\dfrac{C}{C_c}$, we have

$$\frac{C}{C_c} = \frac{(\omega_{ab}/\omega)^2}{2\omega_{ab}\,C_c\,r_b'} - 1 \pm \sqrt{\left[\frac{(\omega_{ab}/\omega)^2}{2\omega_{ab}\,C_c\,r_b'} - 1\right]^2 - \left(\frac{\omega_{ab}}{\omega}\right)^2 - 1} \tag{21}$$

The frequency of oscillation can be calculated from the reactive component of Z_{in} given by Eq. 17 and the equivalent inductance L_e of the crystal as given by Eq. (2). The equivalent capacitance, C_e, is given by

$$C_e = C_c\,\frac{1 + \left[\dfrac{\omega}{\omega_{ab}}\left(1 + \dfrac{C}{C_c}\right)\right]^2}{1 + \left(\dfrac{\omega}{\omega_{ab}}\right)^2\left(1 + \dfrac{C}{C_c}\right)} \tag{22}$$

This equivalent capacitance C_e is in series with the equivalent inductance L_e of the crystal. The frequency of oscillation is slightly below the parallel resonant frequency of the crystal.

Resistivity Measuring Techniques In Semiconductors*

H. GUNTHER RUDENBERG**

This article describes the development and design of direct reading apparatus for resistivity measurements. Various methods of conductive, capacitive and inductive connection to the semiconductor were investigated. For small samples or localized measurements in germanium and silicon, conductive four point probes in a square array are utilized. Spurious rectification at the point contacts and high probe resistances are avoided by the use of a small forward-biasing direct current which stabilizes the series resistance of the probes. Best results have been obtained with small *a-c* measurements using a tuned detector. In *d-c* measurements with a potentiometer or electrometer, forward bias of both voltage probes is assured by proper placement of impedances and shielding all sources of reverse leakage. Thus, resistivities of 1000 ohm-cm may readily be measured with proper surface preparation of the sample and low enough signals to avoid errors from injection effects. A calibration standard using thin silicon slices with alloyed ohmic contacts is used to check the absolute accuracy of the equipment. The apparatus described can be used to measure the surface sheet resistance of diffused layers, and the bias current here isolates this layer electrically from an opposite polarity substrate. Accuracies of 5 to 10% in the range of 0.01 to 1000 ohm-cm are obtainable.

[Tear sheets of this article are available on written request]

MEASUREMENT of resistivity of semiconductors is commonly used in preference to Hall effect measurements[1] for the evaluation of semiconductor doping, both in research and in manufacturing control. From a knowledge of the resistivity ρ and the effective carrier mobility[2], μ, one may obtain the carrier or doping level, N, from

$$N = \frac{1}{e\,\mu\,\rho}$$

where e is the electronic charge. This doping level is of importance in controlling voltage and capacitance of semiconductor devices. Similarly in the design and manufacture of diffused devices, the surface resistance[3] of such layers is an important parameter. Changes of resistivity in heat treating, nuclear bombardment and temperature can occur and often must be monitored.

Apparatus useful in plant and laboratory for such measurements should be simple, require a minimum of sample preparation, preferably be non-destructive, and be useable on production pieces rather than on specially made shapes. Various methods known or described in the literature were compared for their range, ease of use and of calibration, and equipment simplicity. It was desired to measure a wide range of silicon and germanium parts, and hoped that the apparatus would be useful with such new materials as silicon carbide and other intermetallic semiconductors.

As most ordinary contacts to semiconductors give rise to high impedance surface barriers, which would affect the results, the sample resistance cannot generally be measured by applying two probes from an ohmmeter. Probe impedances must be carefully accounted for or their effects minimized and even avoided. Thus the use of separate current and voltage connections leading to a four point probe[4] arrangement are common. In a different approach capacitive[5] or conductive [6] exitation of a current in the semiconductor sample have been described to overcome probe effects. These various methods of coupling to the semiconductor are reviewed for their suitability for this apparatus. Many of the techniques developed for the determination of ground currents and earth resistance are useful here.

Conductive Connection Techniques

A technique which minimizes the effects of resistive barriers at the semiconductor consists of cutting a sample of special shape and using separate current and voltage leads (*Fig. 1*). To further reduce the effects of contact resistance, wide contact areas[7] are used, much wider than the main sample, and these are sandblasted and electroplated. Measurements are made of the voltage between the inner contacts due to a known current impressed through the outer two contacts. This is the most accurate technique developed, but it has the disadvantage of requiring the cutting and fabrication of a special sample from each semiconductor piece under study.

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**Transitron Electronic Corporation, Wakefield, Massachusetts

A useful alternative is the so-called "one probe" method, where a single traveling voltage probe is used to find the voltage change with position along a uniform sample stick, and from this the resistivity profile is evaluated *(Fig. 2)*.

A further simplification derives from the recent developments of so-called ohmic alloyed contacts. Such contacts may be alloyed onto the sample, providing extremely low contact resistances of fractions of an ohm to a rectangular bar of semiconductor material of known dimensions. This allows the measurement of the bar resistance on an ohmmeter or a bridge. In the method adopted for calibration of the instrument to be described, a slice of germanium or silicon has such contacts alloyed one half inch apart *(Fig. 3)* and the piece is then cut off to one half inch width. The thickness w is measured with a micrometer and the sample resistance calculated from the measured sheet resistance by the relation

$$\rho = R_s\, w$$

Contacts are gold-antimony for n type material and gold-gallium for p type material to obtain negligible contact resistance. The advantage of this technique is that it uses slices and contacts similar to those used in device manufacture. The only drawbacks are the sample fabrication, and the possibility of affecting the resistivity by heat treatment during alloying at 500°C.

It must be remembered that the four probe technique minimizes the effects of current probe impedance, but still necessitates the use of a high impedance current source and a voltmeter or potentiometer of much higher impedance than the probes to avoid large errors.

The high impedance voltage measurements have been made both with *d-c* using a potentiometer or electrometer, and with *a-c* by means of an audio frequency current impressed through the sample and a tuned high impedance voltmeter connected to the voltage probes. In the latter case stray capacitances must be avoided so as to keep the impedances high.

Contactless Measurements

A capacitive coupling method has been described for completely avoiding contact resistance, and applied to a two-terminal measurement[5] *(Fig. 4)*.

Two collars of metal foil replace the probes, and a high enough radio frequency is used so that any contact resistance is completely shunted by the contact capacitance. Measurement of the impedance of the sample provides a resistance term which is the sample resistance, from which the resistivity is readily computed. This method is especially useful in the measurement of very high resistivity materials in excess of a hundred ohm centimeters, and to long uniform bars or crystals. It so happens that the commercial impedance bridge which is most suitable for these measurements is direct reading in terms of a parallel equivalent circuit, thus requiring additional

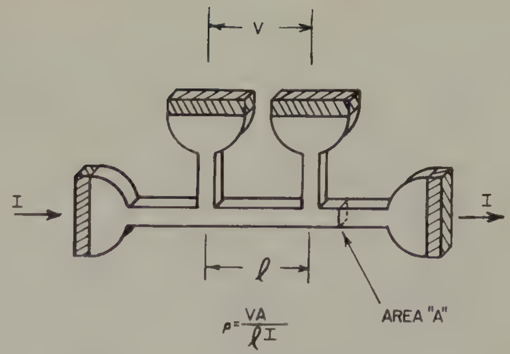

Fig. 1—Resistivity "bridge" shaped sample.

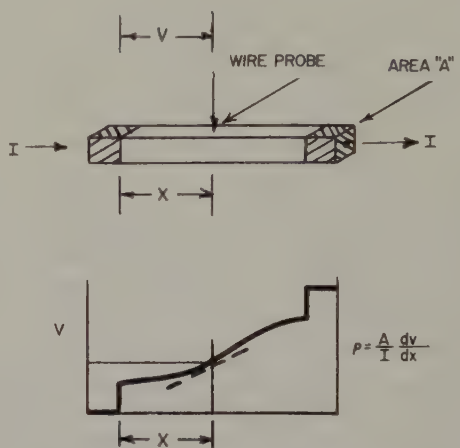

Fig. 2—The "One Probe" method.

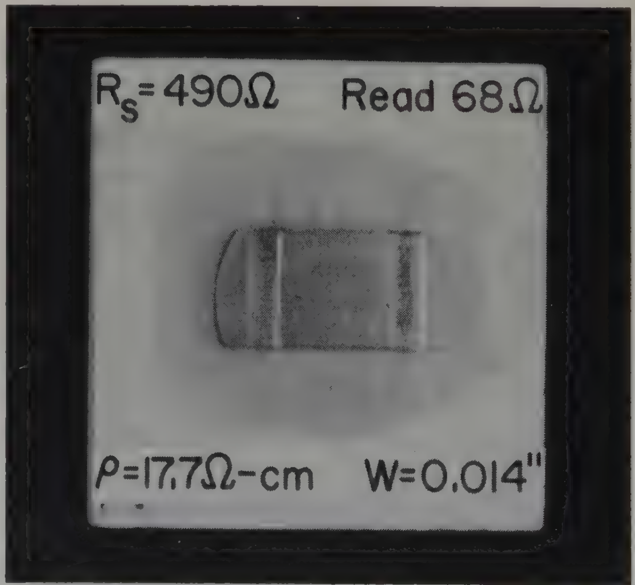

Fig. 3—Silicon standard sample slice.

computations to obtain the equivalent series resistance. A useful frequency of operation is one megacycle, using a General Radio Twin-T Impedance Bridge and a shielded radio receiver as detector. The technique is well suited for measuring the average resistivity of special silicon crystals, where the computations involved are justified.

An inductive method[6] is also possible, and applications of this have been developed. The principle consists of inducing a circulating current from an adjacent coil into the surface of the semiconductor *(Fig. 5)* and determining the resistivity from the back *emf* induced in that coil from the circulating current. It is most suitable to measuring the lowest resistivities of semiconductors, and a similar method has been used for metals to determine plating material thickness or conductivity.

Difficulties lie in the narrow range of resistivities accurately measurable with any one coil, and the fact that exact calculation is difficult. Thus empirical calibrations are resorted to, which still require initial measurements by other techniques.

Four Point Probe Methods

Although the contactless methods are very elegant, their narrow range and more elaborate instrumentation restricts their usefulness. Experience with the four point method had demonstrated its simplicity, and had indicated that considerable improvement in range and accuracy might be obtained from a careful study of the contact resistance problem. An *a-c* instrument[8] had been available for some time, *(Fig. 6)*. This consisted of a low impedance 1000 cycle oscillator, a switched set of series resistors, and a tuned 1000 cycle vacuum tube voltmeter of moderate input impedance. Isolation transformers in both oscillator output and voltmeter input circuits provided the necessary balancing of signals to drive the symmetrical four-probe circuit. Adjustment of current was obtained by switching it through a standard resistor prior to the measurement.

The generator is a Neucor DK1 1000 *cps* oscillator and the tuned voltmeter is a standard Hewlett Packard 415B variable gain voltage indicator, having the meter scale replaced by one with a linear voltage scale *(Fig. 7)*.

This system had given excellent service with germanium resistivity measurements, and for low and medium resistivity silicon material. The apparatus is built up in four blocks, the purchased oscillator and voltmeter, the transformer-resistor switching box and the probe unit. The latter has been designed to provide a constant spacing of one millimeter between adjacent probes with sufficient (5%) accuracy, otherwise variations of probe spacing would affect the resistivity readings. Probes are of hard material, such as tungsten or carbide, and are held in an insulating[9] nylon or Kel-F block *(Fig. 8)*, with only the tip of each probe protruding. Thus excessive pressure on

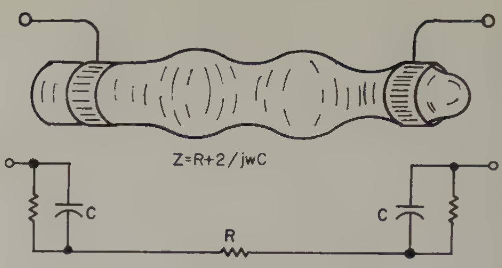

Fig. 4—Capacitive connections.

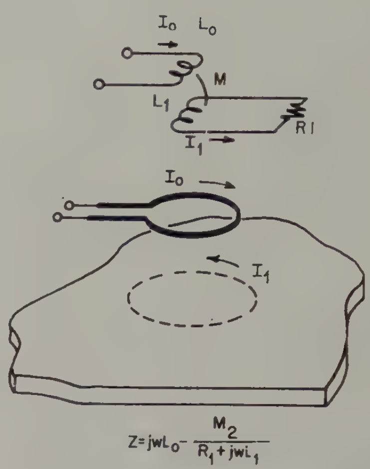

Fig. 5—Inductive method.

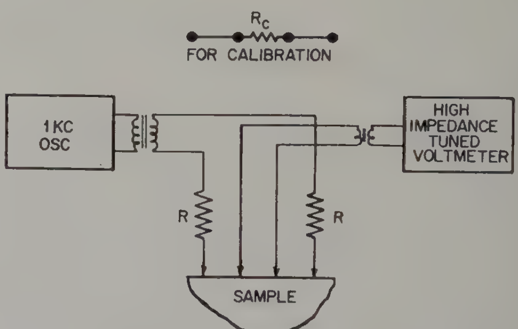

Fig. 6—Diagram of "Four-Probe" method.

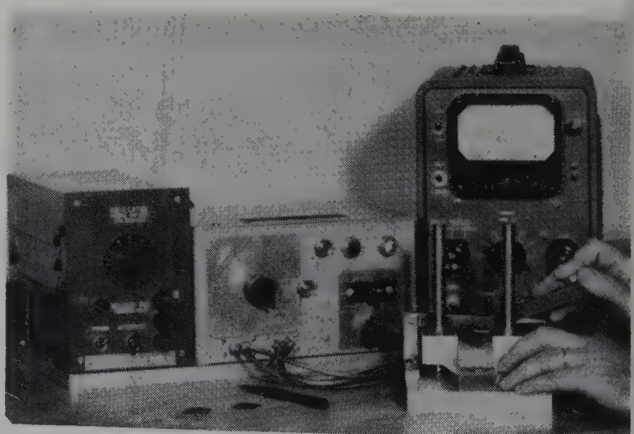

Fig. 7.—Photo of complete apparatus.

the spring-loaded probes would only bring the resilient insulating block down on the sample, preventing damage to the sample by excess needle pressure.

Normally probes are an "in-line" array[10] but for many measurements on small samples a square array is used (Table I). This has the advantage of a smaller total extent of the fringing fields around the probes for the same probe spacing, but has only half the sensitivity of the linear probe array. Nevertheless, with a 40 mil square array, a ⅛ inch diameter semiconductor pellet may be measured with fair accuracy, which could hardly be done with an in-line array of four probes spaced 40 mils each.

Probe contact resistances are minimized by measuring resistivity on freshly lapped surfaces. In addition, probe points are kept sharp and a force of 1 to 2 pounds is applied to the four-probe array by means of springs to provide pressure of the probe tips against the sample.

Although initially satisfactory, increased resistivities now obtained with silicon have lately required further improvements, so that a method to lower probe contact resistances was developed.

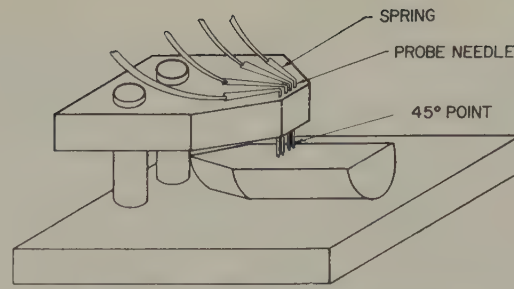

Fig. 8—Four-point probe assembly.

Current Injection And Probe Resistance

A plot of the current-voltage characteristic of a point contact on a semiconductor surface illustrates the well known diode curve *(Fig. 9)*. At low inverse and forward currents this consists of the contact leakage resistance and saturation current, and the junction voltage drop is given by the Schottky relation.

$$I = I_o\,(exp\;\alpha\,V - 1)$$

This leads to the differential resistance or slope of the curve

$$R = 1/\alpha\,(I+I_o)$$

The factor $1/\alpha$ is usually 25 millivolts, although point contacts often show other values. For a good semiconductor or a true surface barrier this is 25,000 ohms for 1 microampere of forward current, and silicon saturation currents may be even lower, with still higher resistances. Thus for reverse currents ($I = -I_o$) the contact junction resistance is extremely high, and at zero current it is still appreciable. The contact resistance would be lowered to quite reasonable values at a forward current of a milliampere. At larger forward currents, the so-called spreading resistance of the contact must be added, given by *Fig. 10.*

$$R_s = \frac{\rho}{2\pi d}\ \text{(round contact), or } R_s = \frac{\rho}{4d}\ \text{(flat contact)}$$

where d is the diameter of the contact area touching the semiconductor surface, and e its resistivity. For a reasonable point diameter (0.04 mil or 10^{-4} cm) and 100 ohm-cm resistivity this is an appreciable spreading resistance of 150,000 ohms.

It is readily apparent that the junction resistance may be reduced to any desired value by injecting a forward current through the probe, and that a few microamperes are sufficient to reduce this resistance well below a few thousand ohms so as to have negligible effect on the measurements. Fortunately in many cases one may obtain a lowering of the spreading resistance portion of the contact resistance by the same current. This is due to the injection of minority carriers into the semiconductor, which lowers its effective resistance locally under the point. Naturally, too large an injected current would flood the space between probes with sufficient additional charges so as to lower the overall resistivity, leading to erroneous measurements. Nevertheless, by proportioning the injecting current *(Fig. 10)* so that the extent of the region of low resistance under each probe is much smaller than the probe spacing, say about one mil diameter, one can obtain a 25 fold reduction from the spreading resistance of our example. This condition

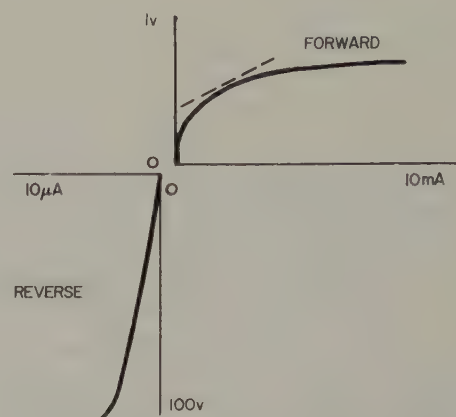

Fig. 9—Diode curve of probe point.

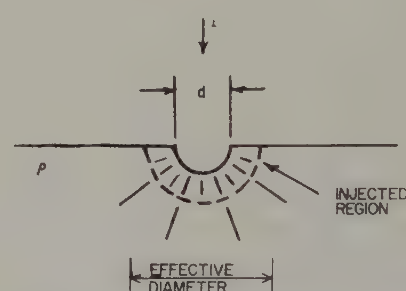

Fig. 10—Spreading resistance and injection.

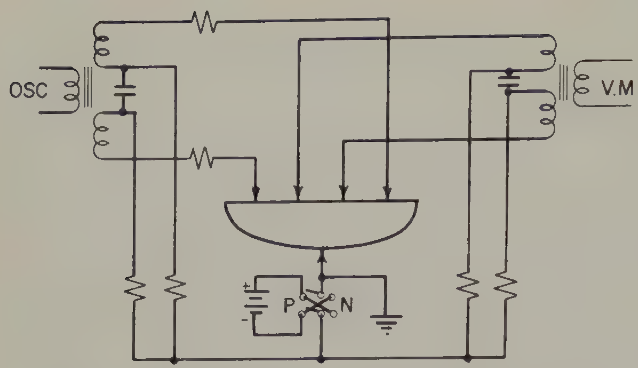

Fig. 11—A. C. measurement with forward bias.

sets an upper limit to the injecting current. For example, the limit is 10 microamperes for 100 ohm-cm material, leaving a junction resistance of 2,500 ohms and a spreading resistance of 6,500 ohms, totaling less than 10,000 ohms. Such contact resistance would be sufficiently low compared to any reasonable transformer and voltmeter input impedance as to be readily neglected.

Should the probe contacts be only slightly injecting, or the lifetime of carriers in the semiconductor be very short, much larger currents could be used and would be required to lower the junction and spreading resistances. In fact, the resistivity readings may be monitored to determine the value of current at which heating or injection effects affect the results. Fortunately it is the high resistivity material, such as silicon, that has the longest carrier lifetime; and it is here that the technique of controlled current injection is most needed and also most applicable.

The current injection is readily accomplished by superimposing upon the *a-c* probe current a small *d-c* current, (*Fig. 11*). Now a fifth contact is needed to the sample, to return these currents. Either an extra probe on the upper side of the sample or the ground-plate supporting the sample have been used equally successfully for this added connection. A considerable voltage may be needed to obtain the small injecting forward current through the probes, as this fifth contact is back-biased to the semiconductor sample. A considerable voltage barrier exists and must be overcome at this extra contact. Naturally, the current direction is reversed for samples of opposite polarity type.

A similar analysis is applicable to the *d-c* operated apparatus *(Fig. 12)*. Here the direct current enters the sample by one and leaves by the second current probe, so that one of these is forward and the other reverse biased. The voltage difference between the two voltage probes then provides the measurement from which the resistivity is evaluated. Now it is seen from the probe characteristic *(Fig. 9)* that a small leakage current, say one microampere, in the forward direction will only displace the forward voltage drop by a very small amount. But a similar reverse current could swing the floating probe voltage in the inverse direction by 10 to 100 volts. Thus it is important that no leakage current (60 cycle *a-c* included) ever brings the voltage probes into their inverse characteristic. This is ensured in this apparatus by applying small, equal forward currents to both voltage probes, or at least connecting equal high resistances from these probes to the forward-biased one of the current probes. All leakage currents from the reverse-biased current probe and from that side of the voltage supply and of the probe assembly must be avoided. This may be accomplished by placing a guard-ring or grounded shield around the wiring from that side. It must be remembered that voltages of several hundred volts may exist between that probe and the semiconductor surface, and that this could otherwise cause considerable leakage of current.

Other methods of carrier injection had been tried to move the probe characteristic to a low resistance region. Light and heat are both suitable, but not as useful, as their effect does not decay away from the probes like the injected current does. Injection of extra carriers due to light, however, has the advantage that the fifth contact is now biased in the forward direction by the light-generated return current, so that all probes have a low contact resistance.

Sample Size Corrections And Diffused Layers

The applications of this apparatus are greatly increased by its ability to provide measurements of the resistivity, not only of bulk samples or crystals, but also of slices and moderate size dice of diode and transistor parts. The change in readings to be expected when using samples of small dimensions has been calculated and presented for the in-line probes.[10] For a square probe array similar computations may be made. The values for thick and thin

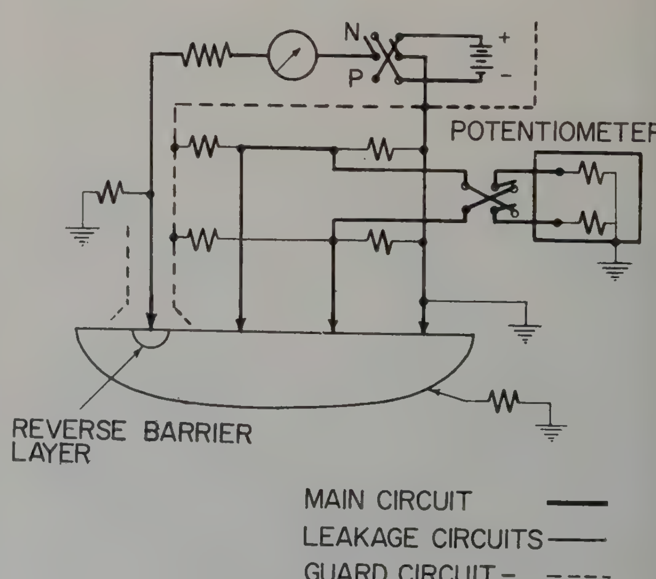

Fig. 12—D. C. measurement with guard circuit.

samples areas are presented in Table I. Most of the work described here involves measurements on thin slices, where either type of probe essentially reads the effective sheet resistance. Where an apparatus is initially designed and calibrated to be direct reading in resistivity for a large (semi-infinite) crystal, a correction curve[4] shows the calibration value or reduction in input current to be used to obtain a direct reading of resistivity for a given wafer thickness. Conversely calibration may be made to make the apparatus direct reading on sheet resistance, necessitating a correction[11] when layer thicknesses exceed the probe spacing. These curves are presented in *Fig. 13*.

Sheet resistance readings on diffused layers are also readily taken. Diffused surface layers on one or both sides of a similar polarity substrate wafer add to the sheet conductivity of the wafer, so that *(Fig. 14-A)*

$$1/R_s = 1/R_{s0} + 1/R_D \text{ (or } + 2/R_D)$$

where R_D is the sheet resistance of the diffused layer and R_{s0} the original measured sheet resistance of the thin wafer. A more accurate calculation might have to be applied to thick wafers. In case the diffused layer is of opposite polarity from that of the substrate wafer, a *p-n* junction *(Fig. 14B)* effectively isolates the substrate and the other side from the measuring circuit. This is especially noticeable in the case of the apparatus described here with a bias current, which reverse biases such a diffused junction. Only occasionally are exceptions noticed when evaluating very shallow diffusion runs. In fact with good diffusion runs the bias return contact must be made directly to the diffused layer, as the junction to the substrate may block the bias current completely.

The relationship between diffusion depth, surface concentration and the resulting sheet resistance of the diffused layer is known [3]; suffice it here to say

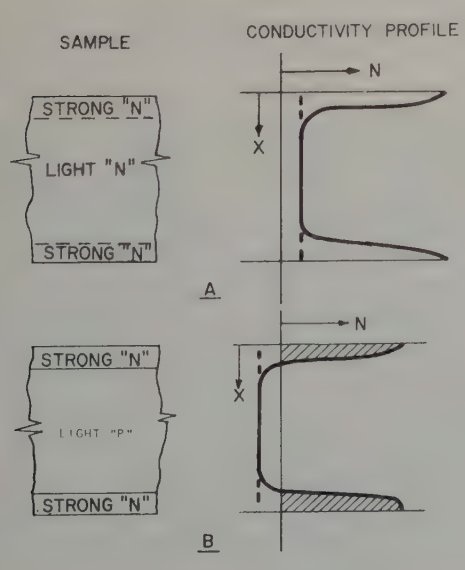

Fig. 14—Diffused surface layers.

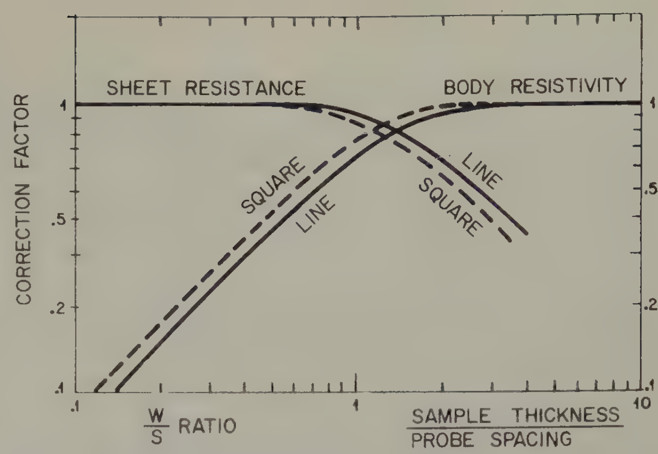

Fig. 13—Correction curves for thin slices.

that the sheet conductance $1/R_s$ is a direct measure, with an average carrier mobility μ, of the total number of dopant atoms, *M*, diffused per unit area into the surface,

$$1/R_s = e\,\mu\,M$$

determined by the product of surface concentration and diffusion depth. When adjusted to read sheet resistance, this apparatus is used for diffusion control.

Calibration and Accuracy

To make the apparatus direct reading the current in the appropriate equation (Table I) is adjusted to produce a unity voltage scale reading for a given value of resistivity. This is done by choice of the calibrating resistor. During "calibration," *(Fig. 6)*, the current flows through the comparison resistor and is read on the same voltmeter so that $IR_c = V_c$. Thus a full scale reading of 1 ohm-cm is obtained when the current has been adjusted to give the same full-scale voltage reading across an R_c of 1.6 ohms with in-line probes of 0.1 cm spacing.

The sheet resistance readings are obtained by dividing the "resistivity" readings by 7.2. Alternately, a calibrating resistor of 0.11 ohms would make the apparatus "direct" reading in sheet resistance with

TABLE I

RESISTIVITY FORMULAE

PROBES / SAMPLE	In-line (s s s)	Square (s)
THICK CRYSTAL	$\rho = 2\pi s\ V/I$ $= 6.28 s\ V/I$	$\rho = 2\pi s\ V/1.203 I$ $= 5.23 s\ V/I$
THIN SLICE w	$\rho_w = 4.53 w\ V/I$	$\rho_w = 9.07 w\ V/I$
RATIO, ρ_w/ρ_∞	0.72 w/s	= 0.85 w/s
SHEET RESISTANCE	$R_s = 4.53\ V/I$	$R_s = 9.07\ V/I$

square probes, or 0.22 ohms for in-line probes of 0.1 cm spacing.

An assumption underlying the design of the instrument is that the initially set current is actually flowing through the sample under test. This may be ensured in the *d-c* instrument by monitoring this current with a meter. In the *a-c* version this is not easily done, so that the accuracy of this assumption is enhanced by using fairly high series resistance in the current supply, ten times larger than the highest expected series resistance of the current probes. This is why it is important to reduce their contact resistance also. In addition, checks are run with sample slices *(Fig. 3)* of high resistivity, having had their resistivity determined by the methods described previously. This checks instrumental errors, errors in probe alignment and problems of contact resistance. As increased contact pressure and current also lowers contact resistance, the reproducibility of readings to such changes as well as their accuracy within 5 percent on accurately known samples is taken as confirmation of the reliability of this apparatus. Probe needles eventually lose their sharp points, and needle replacement usually will correct any deterioration of performance. Thus the apparatus has given 5 percent accuracy up to 100 ohm-cm in silicon and 20% to 1000 ohm-cm with more careful surface lapping and cleaning. It has actually been used to measure the resistivity of etched germanium samples. Some care to avoid stray capacitance effects, and shielding and balancing of leads is necessary for the highest resistivity readings.

For measuring very low resistivities, the *a-c* apparatus must have the push-pull circuits carefully balanced, again to avoid stray direct coupling. Here a two-probe method and *d-c* measurements are very satisfactory; one must only take care that the current through the sample does not heat it too much. Probe resistance and injection effects are small, and do not limit performance.

It must be remembered that the voltage difference across the probes is quite minute. Taking the current amplitude to minimize injection at 10 milliamperes for 100 ohm-cm, a 0.1 centimeter spacing of linear probes gives 1.5 millivolts full scale. Using the *a-c* technique with *d-c* injection, the *a-c* signals should be ten times less, or 150 microvolts. On the other hand stray signals and direct feedthrough come from 1 volt levels, so that considerable care is necessary to obtain good performance. Spurious rectification at the probe from 60 cycle signals is not to be underestimated. It will not directly affect the *a-c* amplifier tuned, say, to 1000 cycles, but it may bias the probe contact into a region of high resistance.

Conclusion

Some of the problems encountered in making reasonably accurate routine resistivity measurements of semiconductors have been presented. Contactless measuring techniques have been reviewed, and a novel method of lowering probe contact resistance by forward current injection described. This has led to the development of a simple measuring apparatus covering a wide range of resistivity with reasonable accuracy. Normally in-line probes are used, but for small pieces and for checking uniformity of resistivity over a slice the square array probes are preferred because of their smaller extension.

In germanium the full range of magnitude from very low to intrinsic resistivities are readable. In silicon the upper limit of the *a-c* apparatus is near 1000 ohm-cm as presently built, and higher ranges are being measured with a carefully shielded *d-c* apparatus. On these highest ranges, surface preparation of the sample, such as lapping and cleaning in hot caustic, are essential. For silicon carbide at room temperature, some difficulties are encountered above several ohm-cm. However, a set of probe supports of Kel-F and one of Lava ceramic have been used and the sample measured at various elevated temperatures on top of a hot-plate. Thus silicon-carbide samples can be determined.

Acknowledgement

The author is grateful to many Transitron associates who have stimulated this work. The original *a-c* measuring apparatus was due to N. deWolfe and the square array probe to E. Simon.

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Alloying With Controlled Spreading in Silicon Transistors*

Part 2

J. ROSCHEN† T. J. MILES† C. G. THORNTON†

Surface spreading of the electrodes in silicon alloy transistors greatly affects the performance and uniformity of the device characteristics. With conventional radiant alloying techniques and low edge dislocation density silicon, electrode areas may increase more than 100 percent. In the silicon surface-alloy transistor, used in this investigation, spreading was found to occur on the heating portion of the alloying cycle and to be strongly dependent on orientation for (111) oriented material. Use of (100) and (110) oriented silicon essentially eliminates spreading, but results in shorted transistors. On lapped surfaces and thick silicon oxide films, the identity and the retrictive action of the crystal plane is lost. Thermal gradients in the silicon produce a directional movement toward the hot zone that is also strongly dependent on orientation.

These spreading problems are alleviated through an extremely rapid rate of heating: on the order of 9,000 to 18,000°C/min. The dissolution of silicon is accomplished by an unsaturated solution at the final alloying temperature and spreading is essentially eliminated. Rapid heating, coupled with silicon having a low density of edge dislocations and close control of pre-alloying base-width, evaporated aluminum film thickness, final alloying temperature, and cooling cycle results in junctions that are planar-parallel with a significant improvement in the distribution of electrical characteristics.

Alloying Cycle

One of the approaches to solving the spreading problem is an alteration of the alloying cycle. It was established early in the investigation that spreading occurred during the heating portion of the alloying cycle. For instance, heating at a rate of approximately 450°C/min. to 900°C with a quick quench of <20 seconds to room temperature did not produce a noticeable reduction in spreading when compared to a slow cooling rate of <50°C/min. A slower rate of heating than 450°C/min. greatly aggravated the spreading problem. Extending the time at the equilibrium alloying temperature had a negligible effect on spreading.

A relative comparison of spreading over the range of alloying boat temperatures of 600°C to 890°C indicates that spreading increases rapidly with a higher final alloying temperature. The photomicrographs in

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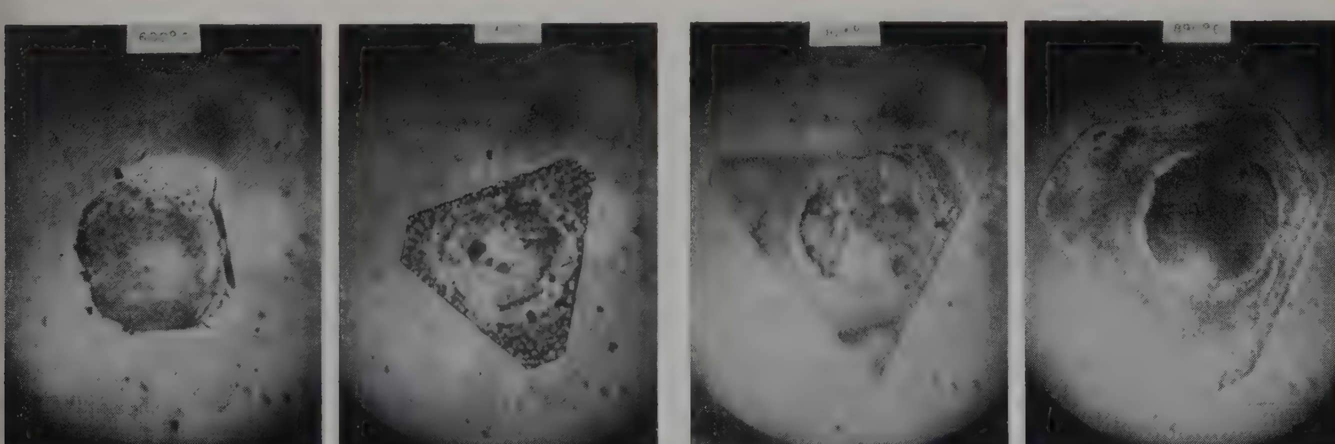

Fig. 13—Effect of temperature on spreading. Magnification ≈100X.

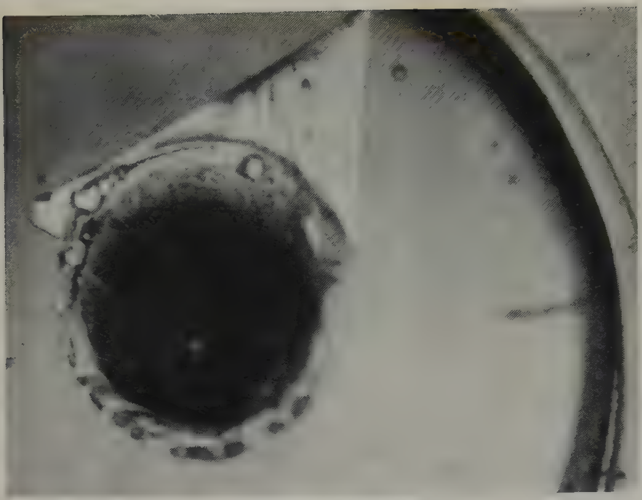

Fig. 14—Effect of thermal gradient on directional movement of molten zone. Magnification ≈150X.

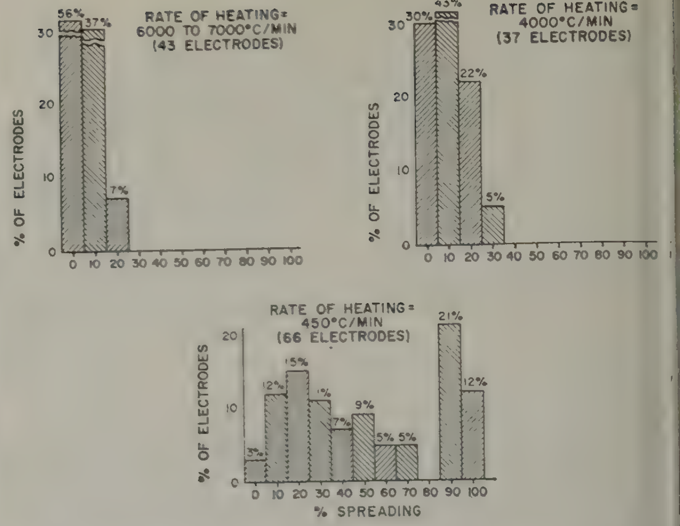

Fig. 15—Effect of heating rate on the distribution of spreading.

Fig. 13 illustrate this spreading for four end temperatures from 600°C to 890°C. The equilibrium alloying time at each temperature was five minutes with a heating rate of approximately 450°C/min. and a cooling rate of approximately 200°C/min. These samples were chosen to indicate the extremes in spreading that may be observed for a given alloying temperature. The rate of movement of the sides of the triangle is approximately 4 times less than that of the apexes. The maximum surface movement from the initial circular geometry for each of the four temperatures is tabulated below. At 890°C the electrode area has more than doubled.

Temperature (°C)	Maximum Movement (mils)
890	4.9
825	4.2
750	2.1
600	1.0

The above data indicates that, from the spreading aspect, a lower alloying terminal temperature produces less spreading. However, the aluminum solubility in solid silicon is retrograde,[9], [10] and for increased conductivity of the recrystallized region and higher injection efficiency, the highest possible alloying temperature consistent with fabrication techniques is desirable. Conductivity of the recrystallized region, from four point probe resistivity measurements (tabulated below), indicates a five-fold improvement for 900°C over 600°C as the end alloying temperature.

Alloying Temperature (°C)	Conductivity (ohm^{-1}—cm^{-1})
600	11
700	15
800	20
900	50

Another factor observed to affect electrode configuration is the temperature gradient across the silicon blank. *Fig. 14* is a photomicrograph illustrating the directional movement of the molten zone in one minute after a thermal gradient in excess of 500°C/cm with a mean zone temperature of approximately 900°C had been established. The directional movement is toward the hot zone and is strongly dependent on orientation. The rate determining factor for this movement appears to be a solution-diffusion-recrystallization phenomenon similar to that reported by Wernick.[11], [12] Thus, one of the factors to be controlled during alloying is the thermal gradient.

From these experiments, and those of Mueller[1], Pankove[2], Goldstein[3], and Wernick[11], [12], it is seen that the solution to the spreading problem lies in the control of the solution rate on the rising portion of the alloying cycle and the elimination of thermal gradients across the blank. The slower the dissolution rate, the greater the differentiation between atomic planes having different solution rates. However, with an extremely rapid solution rate, the crystal forces are no longer predominant and dissolution proceeds more uniformly in all directions. Thus, by rapid heating to the equilibrium alloying temperature, alloying takes place rapidly and uniformly in all directions at the high equilibrium temperature. This process continues until the solution becomes nearly saturated, after which the leveling action of the (111) plane occurs to produce planar-parallel junctions.

In order to obtain the rapid heating that is effective in limiting spreading, conventional radiant alloying furnaces and graphite alloying boats with a large mass are not satisfactory because of the thermal inertia of the boat. In practice, *rf* heating with a thermal load as small as possible is used to obtain an extremely rapid temperature rise.

Where heating rates of 1500°C/min. produce satis-

factory results in germanium transistors[1], heating rates of 6000 to 9000°C/min. over the temperature range of 550°C to 900°C were found to be necessary to produce a substantial reduction in spreading in silicon. For complete elimination of spreading, rates of the order of 18,000°C/min. are required.

In *Fig. 15* the effect of changing the heating rate from 450°C/min. to >6000°C/min. on the distribution in spreading area is indicated. As shown in the graphs, the spreading was reduced from an average increase in area of 52% at a heating rate of 450°C/min. to 5% at 6000 to 9000°C/min.

With extremely rapid heating and close control of (1) pre-alloying base-width, (2) evaporated aluminum thickness, and (3) equilibrium alloying temperature, silicon surface alloy transistors are being fabricated from low dislocation density silicon with very little spreading and considerable improvement in electrical characteristics. This improvement is illustrated in *Fig. 16* where distribution plots of current gain (h_{fb}), input impedance (h_{ib}), and output capacitance (C_{ob}), of transistors fabricated with a heating rate of >6000°C/min. are compared with transistors heated at a rate of 450°C/min. The most significant improvement lies in closer control of the distribution of parameters. The above distributions were obtained from a statistical sampling of over 3500 transistors. Alloying was performed in a dry hydrogen atmosphere with one minute at the equilibrium temperature of 900°C and a cooling rate of 200°C/min. to 600°C. The junctions formed were planar-parallel and similar to that of *Fig. 5*. With further increases in heating rates (on the order of 18,000°C/min or more), an additional reduction in spreading is expected with a corresponding improvement in the distribution of electrical characteristics.

Acknowledgements

The authors wish to extend their thanks to M. Sellani and R. Chu for their assistance in performing some of the experiments, and to W. Macgeorge for the preparation of the pilot run samples with rapid heating.

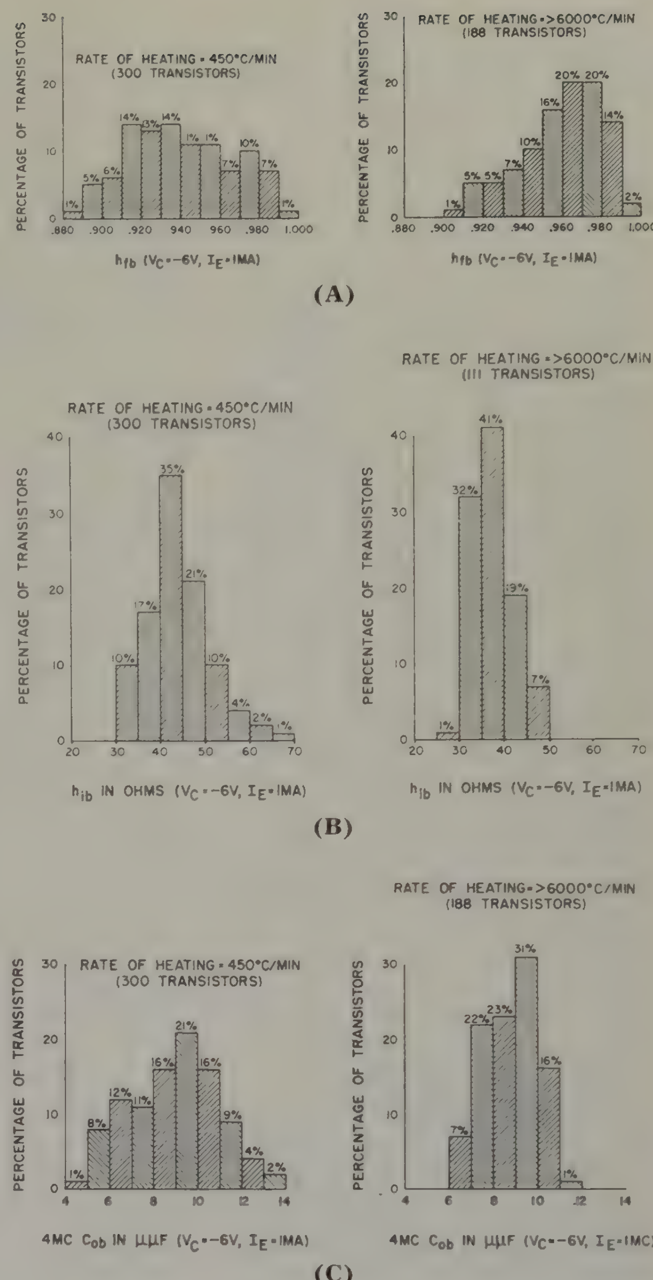

Fig. 16—Comparison of rapid and slow heating rates on the distribution of current gain (A), input impedance (B), and output capacitance (C).

Errata—We regret that the magnification data given in connection with *Figs. 8, 11*, and *12* in Part 1 of this article were erroneous. The following corrections are to be noted. In *Fig. 8* the magnification is ≈ 175X; in *Fig. 11*, it is ≈ 150 X; in the left hand illustration of *Fig. 12*, it is ≈ 1.5X while in the right hand illustration of this figure it is ≈ 55X.

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BOOK REVIEWS . . .

TITLE: The Solid State for Engineers

AUTHOR: Maurice J. Sinnott

PUBLISHER: John Wiley & Son Inc. 1958

The Solid State for Engineers introduces the engineer to the principles underlining the behavior of solid state materials.

The first chapter introduces the subject in terms of the structure of matter starting with basic nuclear physics. Various properties of the elements are listed together with certain basic relationships between mass and energy.

Chapter II entitled "Crystallography" presents matter in the crystalline state. The fourteen theoretical space lattices of Bravais are illustrated and defined in terms of seven crystal system or sets of axes. The crystal is carefully explored and several examples are worked out to illustrate problem technique. Crystalline properties and methods of determination follow in the next chapter, which is devoted to X-Ray and Electron Diffraction.

Chapters IV and V discuss equilibrium and rate processes. Thermodynamic concepts such as entropy and enthalpy are used to present the phase concept or relationship between variants, components and number of phases of a given system. These concepts are developed to explain the state of several variables. Rate processes or transformations are explained by both modern rate theory and the older Arrhenius and Boltzmann equations.

The remaining chapters of the book deal with solids in general. Covalent, metallic, ionic, and molecular solids are catergorized in terms of properties, structures and binding forces. There are chapters on deformations and the theory of dislocations. Various electronic and magnetic properties such as the *p-n* junction effect, Zener breakdown, magnetostruction and rectification are discussed in chapters XVII and XVIII. The book concludes with chapters on optical properties and miscellaneous surface phenomena.

The Solid State for Engineers is a unique collection of the principles and data concerning the behavior of material in the solid state, of particular interest to the engineer. The presentation is excellent making the book a valuable adjunct to the library of the transistor engineer.

TITLE: Logical Design of Electrical Circuits

AUTHORS: Rene A. Higonnet and Rene A. Grea

PUBLISHER: McGraw Hill 1958

Boolean algebra or the mathematics of logic was devised in the eighteen fifties and until recently was one of the more obscure sciences. *Logical Design of Electrical Circuits* is a book written to explain switching circuitry in terms of Boolean algebra.

The first chapter introduces the reader to the theory of sets or groups of classifications. Marbles are used to illustrate the generality of the treatment. The various logical operations of addition, subtraction and multiplication are clearly defined and expressed in terms of the circles of Euler. Classification of combinations, permutations, symmetries and various operations for cases up to four variables are illustrated and listed.

Chapter II deals with two-terminal networks. The relay tree or fanning-out circuit is presented. Logical operations such as the sum and product are explained as relay circuit paths. Various complementary circuits and algebraic simplification methods are detailed together with methods of simplification by inspection.

Chapters III and IV deal with geometrical representations of combinations and simplification of circuits. Two relay combinations are represented by a plane, the case of three relays or three variables by a cube. Circuit simplification by elimination of duplicate paths introduces the study of topological forms or configurations of the circuit.

The remaining chapters of the book treat a variety of topics. Sequential circuits are especially well treated in Chapter X. Chapter XI is a very clear presentation of the electrical characteristics of relays and methods of obtaining special circuit performance. Chapter XII deals with rectifiers and vacuum tubes as switching elements. There is a complete table of circuits for various tube configurations together with their equivalent contact circuits. The appendix contains an extensive table of four relay contact networks.

Logical Design of Electrical Circuits is an intensive study of switching circuits analyzed in a systematic manner. Many examples, tables, and illustrations are used to clarify the text, making this book a well presented, understandable treatment of a complex topic.

TITLE: Solid State Magnetic and Dielectric Devices

AUTHOR: Harold W. Katz, Editor

PUBLISHER: John Wiley & Sons

Solid State Magnetic and *Dielectric Devices* is a rigorous, thorough treatment of ferrite and titanate devices, a topic of vast importance in the field of semiconductors.

The opening chapters develop a theory of solid state in terms of the interaction of electric and magnetic fields in matter. Chapter I introduces electrostatic and magnetostatic field theory starting with Coulomb's law and the H and B field theory. Chapter IV reviews some of the more basic concepts of solid state physics. Paramagnetism, and diamegnetism are explained as ordered and disordered arrays of atomic spins.

The next chapters deal with electrostrictive and magnetostrictive systems. Chapter IV discusses non-linear magnetic and dielectric materials with respect to computer or switching applications.

Perhaps the most useful chapter in the book is Chapter V which deals with electromechanical applications of piezoelectric materials. Here the ceramic transformer and filler are discussed. A fund of design information on methods, modes of vibration, control of spurious response and geometry is presented.

The balance of the book covers a wide range of topics. Magnetic and dielectric amplifiers (Chapter VIII), square-law materials and digital techniques (Chapter IX), measurements (Chapter XI) and a fascinating discussion of magnetic recording (Chapter X) round out the work.

Solid State Magnetic and Dielectric Devices is a fundamental, lucid presentation of the topic. The book is a collection of the work of many eminent authors. It is well written and should serve as an adjacent text to the study of semiconductors.

TITLE: Symposium on Cleaning of Electronic Device Components and Materials

PUBLISHER: American Society for Testing Materials (Publication #246)

The Symposium on Cleaning of Electronic Device Components and Materials is a collection of papers sponsored by the ASTM committee on Materials for Electron Tubes and Semiconductor Devices.

The nature of the modern miniature electron device has stressed certain aspects of component contamination and handling not considered as thoroughly in earlier practice. The papers presented here deal with methods of miniaturization, measurement and evaluations of material contamination and processes of handling and working of pure materials.

There are several interesting papers on laboratory planning and dust control as well as methods of eliminating physical contaminants. A paper by Johnson is an interesting description of "Operation Snow White" a high reliability tube assembly operation. There are many papers on laboratory measurement techniques utilizing new concepts. Of particular interest is the paper by Slater and Donahue on Radiotracers to evaluate parts cleaning. Chemical processes are also reviewed with stress placed on water purity and conductivity measurements. Cause and effect cleaning methods to improve vacuum tube reliability are discussed by Hickle and Crawford. There are several interesting papers on the use of the mass spectometers for gas studies and process evaluation.

The papers presented in this symposium collection are extremely interesting, well prepared and of obvious value to laboratory scientists and quality control engineers. The discussions printed after each paper adds much clarity to the presentations.

TITLE: Germanium, Supplement, System No. 45 of the 8th Edition of Gmelins Handbook of Inorganic Chemistry, 1958, XLIV. (576 pgs., 290 graphs)

PUBLISHER: Verlag Chemie, GmbH., Weinheim/Bergstr. (West Germany). (Available in the USA through any American book importer).

The present Germanium Supplement volume for the first time features bilingual English and German tables of contents. The Supplement to the 1931 Germanium volume encompasses the results of all research published between 1931 and 1953. The 576 pages of the Sup-

plement contrast with the 62 pages of the 1931 volume. As a transition element with both metallic and non-metallic properties, germanium tends to form homopolar compounds like GeH_4. As a homolog of carbon, it has the ability similar to silicon to form organic compounds with Ge-C bonds, having partly chain and ring-form structure. The more than 200 compounds of this type which are now known have been tabulated in the new volume, moveover, several properties and methods of preparation are quoted.

The electrical properties of germanium are divided into several main sections (totaling 255 pages). The first section treats the conductivity phenomena of pure, intrinsic material. In the second section, the electrical properties associated with impurity conduction in germanium are treated; extensive detail on the various methods for production of donors and acceptors in germanium are also included. The third section is devoted to the physics of germanium rectifying junctions and discusses the numerous phenomena of diodes and transistors.

A final section consists of a comprehensive review of the application of germanium diodes and transistors, and presents some technical circuitry data.

In connection with the electrical properties, the photoelectric phenomena are exhaustively described (68 pages), including also the practical significance already acquired by photodiodes and phototransistors, as well as germanium photocells.

The presentation of the physics of germanium may be characterized as one of the most complete monographs on the subject, containing the most recent research results.

TITLE: Electronic Circuit Theory

AUTHORS: H. J. Zimmerman, S. J. Mason

PUBLISHER: John Wiley & Sons 1959

Electronic Circuit Theory is a book dealing with the analytical concept of analysis of electronic circuits, in terms of a model or "idealized abstraction" approach.

The first four chapters develop the concept of diode action as a non-linear circuit phenomena as opposed to linear R, L, and C elements. The idealized diode is considered as both a semiconductor junction and in terms of thermionic and cold cathode emission. Resistive diode circuits are next treated as model circuits utilizing a graphical piecewise-linear approach. This method leads to a thorough consideration of rectification and detection. Many circuits are covered, varying from the simple diode AM detector to the balanced modulator and demodulator.

Chapter V entitled "Transistor Model and Circuits" is a logical outgrowth of the previous diode presentations. A fairly uncommon but highly understandable treatment of the transistor as an emitter-to-base collector-to-base dual diode leads to a very clear concept of transistor action. The piecewise-linear curve presentation is especially helpful here in the analysis of transfer curve characteristics. The equations for impedance and gain in all three configurations are developed and the high frequency equivalent circuits are presented.

The next chapters build the vacuum triode and other control valves in a similar manner of piecewise-linear analysis. A particularly useful treatment of the topic of wave shaping and amplification may be found in chapter VIII in addition to a well written presentation of methods of wave form generation, in the following chapter. The remaining two chapters deal with oscillations in RLC circuits, symmetry, and balanced circuits.

Electronic Circuit Theory is quite useful as a source of basic analytical techniques. This book indicates a method of analysis, while relatively simple, is intuitively elegant, providing a clear understanding of basic circuit phenomena. The book is exceptionally well written, clear and highly readable recommending it as a very useful engineering adjunct.

TITLE: Transistor Workshop Lecture Series

PUBLISHER: IRE—(Boston Section) 1959

This book is a compilation of a series of six lectures presented by the Boston section of the IRE. The lectures comprise a basic course in transistor theory and applications.

The first paper by Rice builds the foundation of the transistor as an amplifying and control device. The various configurations are presented and the transistor is considered as a circuit element in terms of its diode action, with the explanations based upon the devices' characteristic curves. Circuit applications are discussed and several descriptive schematic diagrams are presented to illustrate typical configurations.

The second paper outlines some of the characteristics of the many available transistors and how to select the proper transistor for an application from the parameters of interest. The various terms in use are discussed. Storage time, fall time, delay time and rise time are clearly defined. Static characteristics curves are reviewed and a set of test circuits are given to aid in the undrestanding of the terms. The switching time definitions are graphically illustrated.

The third lecture deals chiefly with transistor circuits used in commercial applications. Design considerations and special "short-cut" approaches are outlined. Special circuits for phonograph pickups are described together with some interesting observations.

Lectures four, five and six comprise the basic body of the book. Here the high frequency operation of transistors is discussed by Watson, together with an interesting comparison between amplifier types (Lecture 4). The applications of high power transistors are treated in Lecture five. Lecture six is an extremely valuable survey of operation of the transistor as a switch and covers a wide and useful range of topics from basic on-off considerations to actual flip-flop and counting circuitry. A set of data charts is bound into the volume providing a useful source of characteristic information to aid in the understanding of the material presented.

The *Transistor Workshop Lecture Series* is an excellent introduction to the transistor and is to be highly recommended to the student as well as the design engineer, not yet familiar with transistors.

TITLE: Proceedings of the National Electronics Conference Volume XIV

PUBLISHER: National Electronics Conference Inc., Chicago 1, Illinois 1959.

Volume *XIV* of the National Electronics Conference is the latest collection of the papers presented at the NEC sessions. The conference itself is sponsored by several engineering societies in conjunction with various colleges and universities throughout the United States. The papers collected in this volume represent the work of many university sponsored research programs in addition to development programs in industry and professional group presentations.

The book is divided into twenty-five topics dealing with the general field of electronics. There are two chapters on transistors in which papers dealing with transistor circuitry, parameters and applications are presented. Additional transistor applications may be found throughout the other sections. Sections on Solid State and Filter Design contain interesting semiconductor applications. The paper on V.H.F. power switching with Semiconductor Diode (page 325) is typical. A high speed transistorized Digital-To-Analog Decoder is discussed in the Computer section.

There are sections on Radar and Radio Navigation. Doppler Radar systems are discussed in some detail. Network Theory, Television, Servomechanisms and Noise are topics also covered by excellent papers. Engineering Management and Engineering Writing and Speech are typical of several non-technical topics treated.

The Proceedings of the National Electronics Conference, Volume XIV is a collection of the results of the latest thinking in many topics in the electronics field. This book deserves a place as a reference work and a source of the latest information in the library of the design engineer.

Stephen E. Lipsky

SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Transistors for Electronic Switching	Bell Labs Rec March 1959	Discussion of the applications of switching transistors in telephone circuits.	T. R. Robillard R. W. Westberg
Use of Active Material in Three-Level Solid State Maser	Bell Syst Tech Jl March 1959	Maser action is based on favorable relaxation time ratio in signal and idler transitions. Relaxation time is affected by doping.	E. O. Schulz-DuBois H. E. D. Scovil R. W. DeGrasse
The Three-Level Solid State Traveling Wave Maser	Bell Syst Tech Jl March 1959	Broadband very-low noise microwave amplification can be obtained from solid state maser action in a propagating microwave structure.	R. W. DeGrasse E. O. Schulz-DuBois H. E. D. Scovil
A Miniaturized Negative-Impedance Voice Repeater Employing Transistors	Comm and Electronics (AIEE) March 1959	Series and series-shunt type repeaters provide transmission gain when inserted in a 2-wire telephone line.	A. S. Howell
How Diodes Generate Functions	Control Engrg March 1959	Description of basic diode-resistor voltage-sensitive network leading to a universal diode function generator	E. J. Galli
Inductance Bridge, Ring Modulator, Transistor Flip-Flop Form Static Switch	Electrical Des News March 1959	An adjustable inductance bridge, a phase-sensitive detector, and a transistor flip-flop are combined to form a static proximity limit switch.	
Series Transistors Expand Operating Range of D-C to D-C Converter	Electrical Des News March 1959	By operating transistors in series a d-c to d-c converter can be operated at higher supply voltages.	
Behavior of Semiconductor and Magnetic Materials in Radiation Environment	Electrical Mfg. March 1959	Theoretical and experimental behavior of several semiconductor and magnetic materials under radiation.	A. Boltax
A Temperature Control System for Transistors	Electronic App Vol 19 No 2 1958/1959	A simple system has been devised whereby the transistors are maintained at a temperature higher than the maximum likely ambient temperature.	H. Kemhadjian
Photoelectric Applications of Semiconductors	Electronic App Vol 19 No 2 1958/1959	A review article in which common properties of all photoelectric detectors are discussed, together with performance calculations.	F. Desvignes
Development and Final Design of Photomultiplier Tubes	Electronic App Vol 19 No 2 1958/1959	The specific problems involved in the technology of photomultipliers are reviewed.	G. Pietri
Transistor Amplifiers for D. C. Signals	Electronic App Vol 19 No 1 1958/1959	Basic types of direct-coupled and "chopper" type amplifiers are examined and compared.	M. Kemhadjian
Hall-Effect Generators	Electronic Design Mar 4 1959	How they work and how they are used.	W. E. Bulman
Standard Transistor Switching Circuits	Electronic Design March 18 1959	Circuits described were designed as compatible building blocks to be interconnected to perform complex functions.	T. A. Prugh
Designing a Transistor NOR Circuit for Minimum Power Dissipation	Electronic Design March 18 1959	The NOT function, AND function, and OR function performed by various combinations of NOR circuits.	E. L. Cox
Design of a Two-Transistor Binary Counter	Electronic Design March 18 1959	Three levels of design suggested, each level aimed for circuit operation under different conditions.	P. Emile Jr.
Keep Junction Temperatures Down	Electronic Design March 18 1959	Steps to be taken to achieve good performance. Graphs enable designer to determine efficiency of a fin.	W. Luft
How to Design for Transistor Reliability-I	Electronic Eq Eng March 1959	Basic reliability criteria for application of transistors are laid down.	J. B. Hangstefer L. H. Dixon Jr.
Design of a Transistor Electronic Switch	Electronic Eq Eng March 1959	Presentation of two simultaneous waveforms on an oscilloscope can be accomplished by a transistor switching instrument.	H. J. Wirth W. M. Oleson
Detectors for Infrared Radiation	Electronic Eq Eng March 1959	The sensitivity and responsibility of thermocouples and bolometers are covered with an introduction to photo detectors.	C. R. Betz
Increase the Input Impedance of Transistor Amplifiers	Electronic Ind March 1959	Description of a transistor amplifier with an input impedance of 8 megohms, a voltage gain of 40 db, and an output impedance of 600 ohms.	A. D. Evans
1959 Transistor Interchangeability Chart	Electronic Ind March 1959	Cross-referencing chart of transistors and their nearest equivalents.	
High-Power Transistor D. C. Converters	Elec Rad Eng (Br) March 1959	The transformer-coupled push-pull circuit is examined in some detail; circuit designs using silicon and germanium power transistors.	T. R. Pye
Transistor Equivalent Circuit	Elec Rad Eng (Br) March 1959	Presentation of a new equivalent circuit for a transistor which is valid at all frequencies where the device gives useful gain.	D. A. Green
Improved R-C Oscillator	Electronics Mar 6 1959	Circuit description and components of the single frequency transistor oscillator designed to operate in the 4 *cps* to 350 *kc* range.	L. H. Dulberger
UHF Transistor Data	Electronics Mar 6 1959	Tabulation of commercially available transistors operating above 300 *mc* with characteristics.	H. Tulchin
Solid-State Thyratrons Available Today	Electronics Mar 6 1959	Tabulation of solid-state thyratrons with pertinent characteristics.	T. P. Sylvan
Transistors Improve Telemeter Transmitter	Electronics Mar 13 1959	Description of balloon-borne transistorized apparatus.	D. Enemark

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Encoder Measures Random Event Time Intervals	Electronics Mar 20 1959	A high-resolution random event encoder using semiconductors is described.	R. J. Kelso J. C. Groce
Digital Recorder Holds Data After Shock	Electronics Mar 20 1959	Description of recorder in which data are stored in ferrite cores that can retain the data even after a 6000-g shock.	C. P. Hedges
New Power Sources for Space-Age Electronics	Electronics Mar 20 1959	Collation of various devices and systems including tables.	D. Linden A. F. Daniel
Junction Silicon Diodes	Elec Exp 3/59 (Xpt) Elektrichestvo No 1 Jan 1959	A study is made of the technology of manufacture and the electrical properties of silicon rectifier diodes.	G. A. Zelikman Ia S. Levenberg I. P. Lukashova Iu I. Sidorov S. V. Frank
On the Conditions Governing the Formation of Avalanche Processes in Point-Contact Transistor Relaxation Oscillators	Elec Exp 3/59 (Comp) Radiotekhi Elek No 1 Jan 1959	Relaxation oscillators based on point-contact transistors may be treated as devices containing a nonlinear voltage or current amplifier.	V. N. Iakovlev
The Effect of Interval Electric Fields in a Semiconductor on its Field Emission	Elec Exp 3/59 (Comp) Radiotekhi Elek No 1 Jan 1959	In order to explain observed experimental characteristics the effects produced by a strong field in a semiconductor must be included.	M. I. Elinson
A Generalized Resistor-Transistor Logic Circuit and Some Applications	IRE Trans Electronic Computers March 1959	Practical limitations such as using precision power supplies and components are discussed; practical circuits worked out.	S. C. Chao
Transistors for Cardiac Conduction System	IRE Trans Med Elec March 1959	Transistor amplifier attached to cardiac electrodes on the atrium and ventricle of a dog alleviates heart block.	E. Watkins, Jr.
Nitrogen in Silicon	J1 App Phys March 1959	The concentration of electrically active impurity states in silicon grown from melts containing around 10^{19} atoms per cm^3 of nitrogen is less than 10^{12} atoms per cm.	W. Kaiser C. D. Thurmond
Effect of Oxide Impurities on the Thermoelectric Powers and Electrical Resistivities of Bismuth, Antimony, Tellurium, and Bismuth-Tellurium Alloys	J1 App Phys March 1959	The thermoelectric powers of these materials depend in detail on the manner in which the thermal gradient is applied during measurement.	R. A. Horne
Sputtering Yield of Germanium in Rare Gases	JL App Phys March 1959	Sputtering yields of Ge bombarded by Ke^+, Kr^+, A^+, Ne^+, and He^+ ions under normal incidence at energies up to 400 ev have been determined.	N. Laegreid G. Wehner B. Meckel
Impurity Compensation and Magnetoresistance in *p*-type Silicon	J1 App Phys March 1959	A new method is proposed for determining the separate concentrations of acceptor and donor impurities in crystals of *p*-type silicon.	D. Long C. D. Motchenbacher J. Myers
High-Speed Switching Diodes from Plastically Deformed Germanuim	J1 App Phys March 1959	Reduced minority storage effect permitted fabrication of diodes with turnoff times of the order of 10^{-9} sec.	G. L. Pearson R. P. Riesz
Recombination Centers on Ion-Bombarded and Vacuum Heat-Treated Germanium Surfaces	J1 App Phys March 1959	After annealing of the bombardment damage, a large number of acceptor type surface states approximately clamped the surface potential.	S. Wang G. Wallis
Associated Donor-Acceptor Luminescent Centers in Zinc Sulfide Phosphor	J1 Electrochem Soc March 1959	Zinc sulfide activated with copper or silver and co-activated with gallium or indium shows two emission bands.	E. F. Apple F. E. Williams
Effect of Various Etches on Recombination Centers at Germanium Surface	J1 Electrochem Soc March 1959	Density, energy levels, and capture probabilities of the recombination centers were measured before and after baking.	G. Wallis S. Wang
The Faraday Effect in Anistropic Semiconductors	J1 Elec & Cont (Br) March 1959	The theory of the Faraday effect in semiconductors is extended to uniaxial crystals with spheroidal energy surfaces.	I. G. Austin
The Measurement of the Temperature Defendence of the Mobility and Effective Lifetime of Minority Carriers in the Base Region of Silicon Transistors	J1 Elec & Cont (Br) March 1959	This paper describes results of similar measurements on silicon transistors, giving however, temperature dependence of the effective lifetime of minority carriers in the base region.	D. M. Evans
Electrical Properties of Stannous Selenide	J1 Phys Soc Jap March 1959	The electrical resistivity, Hall coefficient, and thermoelectric power were investigated on pure and impurity-doped SnSe crystals.	S. Asanabe
A Method of Measuring the Resistivity and Hall Coefficient of Lamellae of Arbitrary Shape	Phillips Tech Rev March 1959	Hall effect measurements can also be made on arbitrarily shaped lamellae in which the stream-line pattern is not at all uniform.	L. J. van de Pauw
AC-DC Electroluminescence	Physical Review March 1 1959	The enhancement of electroluminescence by the superposition of *a-c* and *d-c* voltages has been observed in certain ZnS powder phosphors.	W. A. Thornton
Electroluminescence in Cuprous Oxide	Physical Review March 1 1959	Variations in light output studied as a function of frequency, wave shape, voltage, current, power, and changes in temperature.	R. Frerichs R. Handy
Anomolous Photovoltaic Effect in ZnS Single Crystals	Physical Review March 1 1959	Larger than band-gap photovoltages have been observed in crystals of ZnS with stacking faults.	A. Lempicki
Excitation Spectra and Temperature Dependence of the Luminescence in ZnS Single Crystals	Physical Review March 1 1959	The luminescence was measured for the region 80-500°K and for different wavelengths of existing light.	A. Halperin H. Arbell

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Infrared Absorption of Reduced Rutile TiO_2 Single Crystals	Physical Review March 1 1959	Absorption of plane parallel plates having resistivities ranging from 3 to 0.01 ohm-m have been examined.	D. C. Cronemeyer
Photoconductor Performance, Space-Charge Currents, and the Steady-State Fermi Level	Physical Review March 1 1959	Analysis, via the concept of the steady-state Fermi level, indicates that the performance is limited by the injection space charge.	A. Rose M. A. Lampert
Effect of Pressure on the Infrared Absorption of Semiconductors	Physical Review Mar 15 1959	Measurements have been made on germanium, silicon, and tellurium in the pressure range of 1-2000 atmospheres.	L. J. Neuringer
Transistor Active Filters Using Twin-T Rejection Networks	Proc Inst EE (Br) Mar 1959 Part B	The introduction of a rejection type network into the feedback loop of an amplifier leads to bandpass characteristics similar to those of single tuned circuits.	A. E. Bachmann
Operating Experience with a Transistor Digital Computor	Proc Inst EE (Br) Mar 1959 Part B	This paper describes the performance, and the failure rate of point-contact transistors.	R. C. M. Barnes J. H. Stephen
A New High-Speed Digital Technique for Computer Use	Proc Inst EE (Br) Mar 1959 Part B	A new method is described for realizing logical functions using square-loop ferrite cores and transistors.	D. A. Eldridge
A Method for Testing and Establishing the Rating of Semi-Conductor Rectifiers Under Dynamic Conditions	Proc Inst EE (Br) March 1959 Part C	Principle of operation of the cheater circuit, synchronous switching, and apparatus utilizing commutator switching.	J. I. Missen
The Physical Principles of a Negative-Mass Amplifier	Proc IRE March 1959	This paper describes the physical principles of a new class of solid-state devices used from low frequencies up to very high frequencies in the microwave region.	H. Kromer
The Band Between Microwave and Infrared Regions	Proc IRE March 1959	Generation, detection, control, transmission, measurement factors, problems, and devices discussed.	I. Kaufman
Simple General Analysis of Amplifier Devices with Emitter, Control and Collector Functions	Proc IRE March 1959	Comparative signal amplifying capabilities of lumped solid-state and vacuum tube devices are described in terms of charge control, charge storage, and charge motion.	E. O. Johnson A. Rose
Nonlinear-Capacitance Amplifiers	RCA Review March 1959	A review article providing an explanation of the operations of variable-capacitance amplifiers in simple physical terms.	L. S. Nergaard
Gain-Bandwidth Product for Photoconductors	RCA Review March 1959	Departures from ideal performance analyzed; performance in several well known devices discussed.	A. Rose M. A. Lampert
Properties of Deep Traps Derived from Space-Charge-Current Flow and Photoconductive Decay	RCA Review March 1959	The current-voltage characteristics of a single crystal of CdS have been measured, from which data performance is evaluated.	R. W. Smith
Gains, Response Times and Trap Distributions in Powder Photoconductors	RCA Review March 1959	Trap distributions have been derived from photocurrent decay curves. These show a nearly exponential decrease of trap density with increasing trap depth.	H. B. DeVore
Magnetics for Computers-A survey of the State of the Art	RCA Review March 1959	The present-day applications of magnetics and semiconductor devices to random-access memories and logic switching are surveyed and appraised.	J. A. Rajchman
Unified Representation of Junction Transistor Transient Response	RCA Review March 1959	Result applies to any circuit configuration of the transistor. Specific results usually stated in separate expressions can be derived from a general equation.	A. Harel J. F. Cashen
The Megacoder, A High-Speed Large-Capacity Microminiature Decoder for Selective Communication	RCA Review March 1959	Transistorized device can be preset to respond to any one of one million possible code combinations provided by a bipolar 20-pulse binary code.	H. Kihn W. E. Barnette
Large Scale Preparation of Ultra-Pure Silicon	Res Appd in Ind (Br) Mar 1959	Requirements, difficulties in preparing pure silicon, methods for preparing pure silicon—various processes.	J. M. Wilson
The Application of Dynistor Diode to "Off-On" Controllers	Semiconductor Prod March 1959	Semiconductor device for use in small control circuits, and which provides high output power.	P. F. Pittman
Transistor AC and DC Amplifiers with High Input Impedance	Semiconductor Prod March 1959	A class of transistor amplifiers is described in which high input impedance is achieved with low-input-impedance circuit bias stability.	R. D. Middlebrook C. A. Mead
Transistorized Entertainment type FM Receivers	Semiconductor Prod March 1959	Design considerations of the various stages of a transistorized FM receiver.	H. Cooke
Dislocations In Crystals	Semiconductor Prod March 1959	Many important properties of crystals are determined by the imperfections present within.	J. R. Patel
Research in Preparation of Hyperpure Single Crystal Silicon Carbide	U. S. Govt Res Rep Mar 13 1959 Order LC PB 135 545	The design and operation of a high temperature (2600°C) graphite tube furnace is given.	
Semiconductor Device Set Mx-2009 (XW-1) GP	U. S. Govt Res Rep Mar 13 1959 Order LC PB 135 288	Development of a high voltage 3-phase bridge silicon power rectifier assembly.	
30 MC Silicon Amplifier (Device 22)	U. S. Govt Res Rep Mar 13 1959 Order LC PB 135 555	Fabrication processes are detailed.	M. Dukat G. Freedman
Investigation and Evaluation of an Electronic Gate	U. S. Govt Res Rep Mar 13 1959 Order LC PB 135 438	A crystal diode gate suitable for sampling accurately small changes in resistance 0.1% at the level of 10^5 ohms, is investigated.	O. P. Manley
Evaluation of NOLC 15-Channel Transistorized Electronic Commutator	U. S. Govt Res Rep Mar 13 1959 Order LC PB 135 339	An evaluation is made of a 15-channel transistorized multiplexer for use in a new PAM-FM telemeter or as a commutator.	T. B. Jackson

NEW SPECIAL DIODES

(Continued from August 1959)

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. {See code at start of chart}
1M6.8Z Δ	5.4	8.2	37	3.5	37	1000	.04	MOT
1.5M6.8Z Δ	5.4	8.2	55	2.7	55	1500	.04	MOT
10M6.8Z Δ	5.4	8.2	370	1.2	370	10W	.04	MOT
50M6.8Z Δ	5.4	8.2	1850	.40	1850	50W	.04	MOT
1M7.5Z Δ	6.0	9.0	34	4.0	34	1000	.045	MOT
1.5M7.5Z Δ	6.0	9.0	50	3.0	50	1500	.045	MOT
10M7.5Z Δ	6.0	9.0	335	1.3	335	10W	.045	MOT
50M7.5Z Δ	6.0	9.0	1700	.50	1700	50W	.045	MOT
1M8.2Z Δ	6.6	9.8	31	4.5	31	1000	.048	MOT
1.5M8.2Z Δ	6.6	9.8	46	3.5	46	1500	.048	MOT
10M8.2Z Δ	6.6	9.8	305	1.5	305	10W	.048	MOT
50M8.2Z Δ	6.6	9.8	1500	.60	1500	50W	.048	MOT
1M9.1Z Δ	7.3	10.9	28	5.0	28	1000	.051	MOT
1.5M9.1Z Δ	7.3	10.9	41	4.0	41	1500	.051	MOT
10M9.1Z Δ	7.3	10.9	275	2.0	275	10W	.051	MOT
50M9.1Z Δ	7.3	10.9	1370	.70	1370	50W	.051	MOT

Under Type No.
Ø - Double Anode Type
* - Developmental Type
Δ - Also available with ± 5 percent tolerance

CHARACTERISTICS CHART of SWITCHING DIODES

TYPE NO.	MAT	PIV (volts)	MAX. CONT. REV. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f (mA)	@ E_f (volts)	Reverse Impedance @ 25°C Z (K ohms)	VOLTAGE RANGE E_{b1} to E_{b2} (volts)	Recovery Characteristics TEST CONDITIONS Fwd. I_f (ma)	Rev. to E_b (volts)	$Z_{rec.}$ (K ohms)	@ time (t) (usec)	MFR. {See code at start of charts}
1N643A	Si		200	100	1.0	1.0	100	5.0	40	200	.30	HUG
1N662A	Si		100	100	1.0	20	50	5.0	40	100	.50	HUG
1N663A	Si		100	100	1.0	.10	75	5.0	40	200	.30	HUG
1N818	Si		70	30	1.5		60	20	90	80	.50	CTP
1N837	Si		100	150	1.0	.10	75	30	35	400	.50	HUG
1N837A	Si		100	150	1.0	.10	80	30	35	400	.30	HUG
1N838	Si		150	150	1.0	.10	125	30	35	400	.50	HUG
1N839	Si		200	150	1.0	.10	175	30	35	400	.50	HUG
1N840	Si		50	150	1.0	.10	40	30	35	400	.30	HUG
1N841	Si		150	150	1.0	.10	120	30	35	400	.30	HUG
1N842	Si		200	150	1.0	.10	160	30	35	400	.30	HUG
1N843	Si		250	150	1.0	.10	200	30	35	400	.30	HUG
1N844	Si		100	200	1.0	.10	80	30	35	400	.50	HUG
1N845	Si		200	200	1.0	.10	160	30	35	400	.50	HUG
MA4223	Si	30	30	10	1.1			10	5.0	Complete-8m		MIC
OA41	Ge	90	60	5.0	1.0	400min.	20 50	30	35	50	.50	TKD
SFD109	Ge		90	10	1.5	400	20 50	30	35	50	.50	CSF

CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

TYPE NO.	CLASSIFI-CATION	DESCRIPTION	MFR.
1N269E	1	At 3060Mc.-conv. loss-5.5db max. NR-1.5 times max. At 9375Mc.-conv. loss-6.0db max. NR-1.4 times max.	GAH
1N830	2	UHF Detector, Micro-Min diode	SYL
1N831	1,2	S-Band Mixer, Micro-Min diode	SYL
1N832	1,2	X-Band Mixer, Micro-Min diode	SYL
1N833	1,2	X-Band Detector, Micro-Min diode	SYL
1N836		Parametric Amplifier Diode, Glass Package	HUG
1N2386		Parametric Amplifier Diode, Microwave Package	HUG
1T51		Thermal Compensation Diode;PIV-25V.,Thermal Coeff.-.002V/°C Avg. I-100ma	SONY
1T52		Thermal Compensation Diode;PIV-25V.,Thermal Coeff.-.002V/°C Avg. I-25ma	SONY
KF11	4	Grain boundary photo diode	TKD
OA21	2,6	UHF - Mixer diode	TKD
PHGI	4	30V.max.,Min. sens.-70ma/Lumen;dark I-10ua at 30V	CSF

Notations Under Classification

1. Microwave diodes
2. Mixer or detector diodes
4. Photodiodes
5. Solar Cells
6. Harmonic Generator diodes
7. 4-Layer bistable diodes

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Aug. 14, 1956 to Sept. 18, 1956. In subsequent issues, patents issued from Sept. 18, 1956 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

August 14, 1956

2,759,133 Semiconductor Devices—C. W. Mueller. Assignee: Radio Corporation of America. A semiconductor device comprising a body of semiconductive material having therein zones of different conductivity types separated by a rectifying barrier, and a heat radiating member in intimate thermal contact with said barrier.

2,759,142 Transistor and Electromagnetic Control Apparatus—B. H. Hamilton. Assignee: Bell Telephone Laboratories. In combination: a saturable reactor, a *d-c* source, two transistors, and means for impressing upon the base of one transistor, with respect to a terminal of said source, a potential which may vary for controlling the currents flowing through the control windings of said reactor.

August 21, 1956

2,760,004 Number Group Circuit—W. A. Reenstra. Assignee: Bell Telephone Laboratories. A telephone switching system comprising lines and trunks and a transistor switching network for establishing talking connections between lines and trunks.

2,760,007 Two Stage Transistor Feedback Amplifier—J. C. Lozier. Assignee: Bell Telephone Laboratories. A device including a series negative feedback path between the emitter of a second transistor and the base of a first transistor, and a shunt negative feedback path between the collector of said second transistor and the emitter of said first transistor.

2,760,012 Semiconductor Velocity Modulation Amplifier—R. W. Peter. Assignee: Radio Corporation of America. An arrangement including a wave guide filled completely by a semiconductor, said semiconductor being insulated from the walls of the waveguide and being used for guiding an electromagnetic wave along a path within the semiconductor with a phase velocity less than the corresponding wave velocity in free space.

2,760,013 Semiconductor Velocity Modulation Amplifier—R. W. Peter. Assignee: Radio Corporation of America. A device including a waveguide with phase retardable means comprising a series of planar plates within said waveguide and normal to the direction of flow in a path within a semiconductor.

2,760,060 Ultrahigh Frequency Converter System Having a Crystal Diode Mixer—C. W. Wittenburg, C. C. Hermeling. Assignee: Radio Corporation of America. A device comprising a crystal diode, mixer, a resonant signal input circuit, means for providing a series-resonant signal output path, an oscillation generator tunable within the uhf band, and an intermediate amplifier stage.

2,760,070 Amplitude Stabilized Transistor Oscillator Circuit—E. Keonjian. Assignee: General Electric Company. A transistor oscillator circuit which maintains the amplitude of oscillation at a constant value over a variable frequency range, and which eliminates the need for an auxiliary source of reference potential.

2,760,087 Transistor Memory Circuits—J. H. Felkes. Assignee: Bell Telephone Laboratories. A circuit for the storage of a binary bit of information in the form of either a One or a Zero utilizing a transistor flip-flop circuit.

2,760,088 Pulse Shaping Circuits—G. F. Pittman Jr., R. O. Decker, R. L. Bright. Assignee: Westinghouse Electric Corporation. A pulse shaping circuit for supplying pulses of constant volt-second area to a load in response to input pulses utilizing two transistors and a magnetic core element.

August 28, 1956

2,761,020 Frequency Selective Semiconductor Circuit Elements—W. Shockley. Assignee: Bell Telephone Laboratories. A signal transmitting device comprising an elongated body of semiconductive material, the resistance per unit length of which varies cyclically through a plurality of cycles between the ends of said body.

2,761,095 Selenium Rectifier—S. S. Fry. Assignee: Fansteel Metallurgical Corporation. A selenium rectifier, the blocking layer of which is composed of an organic borate compound having the general formula $(RO)_3B$ Where R is a radical selected from the class consisting of alkyl, aryl, and alkaryl radicals.

September 4, 1956

2,761,909 Multifrequency Oscillator—R. L. Wallace Jr. Assignee: Bell Telephone Laboratories. A two-frequency oscillator which comprises a symmetrical transistor, two feedback paths including two frequency determining circuits, and means for rendering said transistor alternately operative in opposite directions, and means for simultaneously disablin[g] said feedbacks in alternation.

2,761,916 Self-Biasing Semiconductor Cir[cuits] and the Like—L. E. Barton. As[signee]: Radio Corporation of America. A circuit employing semiconductor device[s] connected in cascade relationship tha[t] provides means for adjusting the bia[s] voltages automatically to compensate fo[r] varying characteristics of different semi[con]ductor devices thus permitting [a] change of semiconductors without chang[-]ing the source of bias voltage.

2,761,917 Class B Signal Amplifier Circuit[s] —A. I. Aronson. Assignee: Radio Corpora[-]tion of America. An amplifier utilizing an output stage and a driver stage con[-]nected in cascade direct-coupled relatio[n] each of said stages including a pair [of] transistors connected and biased for push[-]pull class B operation.

2,761,965 Electronic Circuits—A. H. Dick[-]inson. Assignee: International Busines[s] Machines Corporation. A circuit whic[h] provides a plurality of serially arrange[d] counter stages utilizing transistors i[n] which each successive stage has a no[n-]indicating, a primed and an indicatin[g] condition, said circuit being capable o[f] operating as a quinary or biquinar[y] counter.

2,762,001 Fuzed Junction Transistor As[-]semblies—J. S. Kilby. Assignee: Globe[-]Union Inc. A transistor assembly includ[-]ing a metal container having a tinne[d] tab and a terminal, an insulating base i[n] said container, terminals rigidly fixed t[o] said base, and a germanium wafer seate[d] in a recess in said container and in con[-]tact with said tinned tab.

September 11, 1956

2,762,464 Train Speed Control System—C. S. Wilcox. Assignee: General Railwa[y] Signal Company. Train carried apparatu[s] for a speed control system comprising a[n] axle driven frequency generator, a[n] amplifying and high pass filtering cir[-]cuit, means responsive to the voltage produced in the generator coil, and a keyed transistor oscillator having its in[-]termittent output applied to said amplify[-]ing circuit.

2,862,730 Method of Making Barriers In Semiconductors—B. H. Alexander. As[-]signee: Sylvania Electric Products In[-]corporated. A method which comprises bringing a solid germanium body of one

(*Continued on page 56*)

* Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

CHARACTERISTICS CHART of NEW TRANSISTORS

Announced Between May 1, 1959 and June 30, 1959

MANUFACTURERS **(In Order of Code Letters)**

ARA— Advanced Research Associates, Inc.
AEG— Allgemeine Elecktricitats-gesellschaft
AMP— Amperex Electronic Corp.
AEI— Associated Electrical Industries Export Ltd.
BEN— Bendix Aviation Corp.
BOG— Bogue Electric Mfg. Co.
CBS— CBS-Electronics
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
EEVB— English Electric Valve Co., Ltd.
ESEB— Edison Swan Electric Co., Ltd.
FSC— Fairchild Semiconductors Corp.
FTHF— French Thomson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GEM— Great Eastern Mfg. Co.
GTC— General Transistor Corp.
HUG— Hughes Aircraft Co.
HIVB— Hivac Ltd.
IND— Industro Transistor Corp.
LCTF— Labortoire Central de Telecommunications
MIN— Minneapolis-Honeywell Regulator Co.
MOT— Motorola, Inc.
MUL— Mullard Ltd.
NTLB— Newmarket Transistors Ltd.
NPC— Nucleonics Products Co.
PSI— Pacific Semiconductors, Inc.
PHI— Philco Corp., Landsdale Tube Co.
RAY— Raytheon Co.
RCA— Radio Corp. of America, Semiconductor Div.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SONY— Sony Corp.
SPE— Sperry Gyroscope Co.
SPR— Sprague Electric Co.
SYL— Sylvania Electric Products Inc.
STCB— Standard Telephone & Cables, Ltd.
TKAD— Suddeutsche Telefon-Apparate-, Kabel und Drahtwerke
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments
TUN— Tung-Sol Electric, Inc.
WEC— Western Electric Co., Inc.
WEST— Westinghouse Electric Corp.

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics	Gain		MFR. See code at start of charts
				P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	PARAMETER and (condition)	VALUE	
2N699	3,4,5	NPNMe	Si	2000Ø	75	120	80	100#	h_{FE} pulsed	40-120	FSC
2N710	2,5	PNPD	Ge	300	250	15		250			TI
2N1011	3	PNPA	Ge		1.2	80		7Kc	h_{FE}:I_C-3.0A	53	DEL
2N1140	5	NPN	Si	1000		40	40	60	h_{fe}:I_c- 50ma	50	TRA
2N1199	5	D	Si	100	125	20	20	147		25db	PHIL
2N1206	3	NPN	Si	1200		60	60		h_{fe}:I_c- 10ma	35	TRA
2N1207	3	NPN	Si	1200		60	60		h_{fe}:I_c- 10ma	50	TRA
2N1208	3	NPN	Si	85W	3.76	60	60	12	h_{fe}:I_c-2.0A	30	TRA
2N1209	3	NPN	Si	85W	3.76	45	45	12	h_{fe}:I_c-2.0A	40	TRA
2N1212	3	NPN	Si	85W	3.76	60	60	10	h_{fe}:I_c-2.0A	30	TRA
2N1228	2⍁	PNPF	Si	400	337	15	15	1.2	h_{fe}:I_e-1.0ma	14	HUG
2N1229	2⍁	PNPF	Si	400	337	15	15	1.2	h_{fe}:I_e-1.0ma	30	HUG
2N1230	2⍁	PNPF	Si	400	337	35	35	1.2	h_{fe}:I_e-1.0ma	14	HUG
2N1231	2⍁	PNPF	Si	400	337	35	35	1.2	h_{fe}:I_e-1.0ma	25	HUG
2N1232	2⍁	PNPF	Si	400	337	65	65	1.0	h_{fe}:I_e-1.0ma	14	HUG
2N1233	2⍁	PNPF	Si	400	337	65	65	1.0	h_{fe}:I_e-1.0ma	25	HUG
2N1234	2⍁	PNPF	Si	400	337	110	110	.80	h_{fe}:I_e-1.0ma	14	HUG
2N1238	3⍁	PNPF	Si	1000	150	15	15	1.2	h_{fe}:I_e-1.0ma	14	HUG
2N1239	3⍁	PNPF	Si	1000	150	15	15	1.2	h_{fe}:I_e-1.0ma	30	HUG
2N1240	3⍁	PNPF	Si	1000	150	35	35	1.2	h_{fe}:I_e-1.0ma	14	HUG

NOTATIONS

Under Use

1 - Low power a-f equal to or less than 50 mw
2 - Medium power a-f > 50 mw and equal to or less than 500 mw
3 - Power > 500 mw
4 - r-f/i-f
5 - Switching and Computer
6 - Low Noise
⍁ - Revised Spec.

Under Type

A - Alloyed
D - Diffused or Drift
F - Fused
G - Grown
H - Hook Collector
M - Microalloy
Me - Mesa
O - Other
S - Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
ʃ - Tetrode

Under f_{ab}

* Maximum Frequency
# Figure of Merit
△ $f_{\alpha e}$
Ø Minimum
† Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_c

Ø - Infinite heat sink

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. (See code at end of chart)
				P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	Gain: VALUE	
2N1241	3Ø	PNPF	Si	1000	150	35	35	1.2	h_{fe}:I_e-1.0ma	25	HUG
2N1242	3Ø	PNPF	Si	1000	150	65	65	1.0	h_{fe}:I_e-1.0ma	14	HUG
2N1243	3Ø	PNPF	Si	1000	150	65	65	1.0	h_{fe}:I_e-1.0ma	25	HUG
2N1244	3Ø	PNPF	Si	1000	150	110	110	.80	h_{fe}:I_e-1.0ma	14	HUG
2N1247	1	NPN	Si	30	4000	6.0	6.0	5.0	h_{fe}:I_e-100ua	70	TRA
2N1248	6	NPN	Si	30	4000	6.0	6.0	5.0	h_{fe} at 1.0Kc	45	TRA
2N1249	6	NPN	Si	30	4000	6.0	6.0	5.0	h_{fe} at 1.0Kc	37	TRA
2N1252	3,4,5	NPNMe	Si	2000Ø	75	30	20	100#	h_{FE} pulsed	15-45	FSC
2N1253	3,4,5	NPNMe	Si	2000Ø	75	30	20	100#	h_{FE} pulsed	30-90	FSC
2N1254	5	PNPMe	Si	250	550	15	15	25	h_{FE}:I_E-2.0ma	15	HUG
2N1255	5	PNPMe	Si	250	550	15	15	25	h_{FE}:I_E-2.0ma	50	HUG
2N1256	5	PNPMe	Si	250	550	30	30	25	h_{FE}:I_E-2.0ma	15	HUG
2N1257	5	PNPMe	Si	250	550	30	30	25	h_{FE}:I_E-2.0ma	50	HUG
2N1258	5	PNPMe	Si	250	550	50	50	25	h_{FE}:I_E-2.0ma	15	HUG
2N1259	5	PNPMe	Si	250	550	50	50	25	h_{FE}:I_E-2.0ma	50	HUG
2N1267	5	D	Si	100	125	20	20	90*	At 4.3 Mc	25db	PHIL
2N1268	5	D	Si	100	125	20	20	90*	At 4.3 Mc	25db	PHIL
2N1269	5	D	Si	100	125	20	20	90*	At 4.3 Mc	25db	PHIL
2N1270	5	D	Si	100	125	20	20	200*	At 12.5 Mc	25db	PHIL
2N1271	5	D	Si	100	125	20	20	200*	At 12.5 Mc	25db	PHIL
2N1272	5	D	Si	100	125	20	20	200*	At 12.5 Mc	25db	PHIL
2N1275	2	NPNA	Si	386	350	100		.10	h_{fe}:I_e-1.0ma	14	RAY
2N1280	5	PNP	Ge	200	300	16	16	8.0	h_{FE}:I_C- 20ma	60	IND
2N1281	5	PNP	Ge	200	300	16	12	10	h_{FE}:I_C- 20ma	90	IND
2N1282	5	PNP	Ge	200	300	16	6.0	15	h_{FE}:I_C- 20ma	100	IND
2N1284	5	PNP	Ge	200	300	20	15	8.0	h_{FE}:I_C- 10ma	65	IND
2N1291	3	PNPA	Ge		3.0	35	30	.15	h_{FE}:I_C-500ma	40Ø	CBS
2N1292	3	NPNA	Ge		3.0	35	30	.15	h_{FE}:I_C-500ma	30Ø	CBS
2N1293	3	PNPA	Ge		3.0	60	60	.15	h_{FE}:I_C-500ma	40Ø	CBS
2N1294	3	NPNA	Ge		3.0	60	60	.15	h_{FE}:I_C-500ma	30Ø	CBS
2N1295	3	PNPA	Ge		3.0	80	80	.15	h_{FE}:I_C-500ma	40Ø	CBS
2N1296	3	NPNA	Ge		3.0	80	60	.15	h_{FE}:I_C-500ma	30Ø	CBS
2N1297	3	PNPA	Ge		3.0	100	100	.15	h_{FE}:I_C-500ma	40Ø	CBS
2N1298	3	NPNA	Ge		3.0	100	80	.15	h_{FE}:I_C-500ma	30Ø	CBS
2N1299	5	NPNA	Ge	150	.50	40	20	5.0	h_{FE}: 50ma	110	SYL
2N1300	5	PNPMe	Ge	150	300	13	12	40	h_{FE}:I_C- 10ma	50	RCA
2N1301	5	PNPMe	Ge	150	300	13	12	60	h_{FE}:I_C- 10ma	50	RCA
2N1302	2	NPNA	Ge	150	400	25		3.0Ø	h_{fe}:I_c- 20ma	50	TI
2N1303	2	PNPA	Ge	150	400	30		3.0Ø	h_{fe}:I_c- 20ma	50	TI
2N1304	2	NPNA	Ge	150	400	25		5.0Ø	h_{fe}:I_c- 20ma	70	TI
2N1305	2	PNPA	Ge	150	400	30		5.0Ø	h_{fe}:I_c- 20ma	70	TI
2N1306	2	NPNA	Ge	150	400	25		10Ø	h_{fe}:I_c- 20ma	100	TI
2N1307	2	PNPA	Ge	150	400	30		10Ø	h_{fe}:I_c- 20ma	100	TI
2N1308	2	NPNA	Ge	150	400	25		15Ø	h_{fe}:I_c- 20ma	150	TI
2N1309	2	PNPA	Ge	150	400	30		15Ø	h_{fe}:I_c- 20ma	150	TI
2N1313	2,5	PNPA	Ge	175	350	30	20	12	h_{FE}:I_C-400ma	40	TUN
2N1316	5	PNP	Ge	200	300	30	15	15	h_{FE}:I_C-1.0ma	100	IND
2N1317	5	PNP	Ge	200	300	20	12	15	h_{FE}:I_C-1.0ma	95	IND
2N1318	5	PNP	Ge	200	300	10	6.0	15	h_{FE}:I_C-1.0ma	85	IND
2N1335	3,4	NPND	Si	2800	44	120	90	170	h_{fe}:I_c- 30ma	13	PSI
2N1336	3,4	NPND	Si	2800	44	120	90	170	h_{fe}:I_c- 30ma	13	PSI
2N1337	3,4	NPND	Si	2800	44	120	90	170	h_{fe}:I_c- 30ma	13	PSI
2N1339	3,4	NPND	Si	2800	44	120	80	220*			PSI
2N1340	3,4	NPND	Si	2800	44	120	90	250*			PSI
2N1341	3,4	NPND	Si	2800	44	120	100	280*			PSI

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	VALUE	MFR. See code at start of charts
2N1343	5	PNP	Ge	200	300	20	16	6.0	$h_{FE}:I_C$- 50ma	40	IND
2N1344	5	PNP	Ge	200	300	15	15	12	$h_{FE}:I_C$- 20ma	90	IND
2N1345	5	PNP	Ge	200	300	10	8.0	12	$h_{FE}:I_C$-400ma	60	IND
2N1346	5	PNP	Ge	200	300	12	10	12	$h_{FE}:I_C$-350ma	125	IND
2N1347	5	PNP	Ge	200	300	20	12	8.0	$h_{FE}:I_C$- 10ma	80	IND
2N1348	5	PNP	Ge	200	300	40	20	5.0	$h_{FE}:I_C$- 10ma	95	IND
2N1349	5	PNP	Ge	200	300	40	35	10	$h_{FE}:I_C$- 10ma	115	IND
2N1350	5	PNP	Ge	200	300	50	40	8.0	$h_{FE}:I_C$- 10ma	95	IND
2N1351	5	PNP	Ge	200	300	40	30	8.0	$h_{FE}:I_C$- 10ma	65	IND
2N1352	2	PNP	Ge	200	300	30	20	2.5	$h_{FE}:I_C$-1.0ma	70	IND
2N1353	5	PNP	Ge	200	300	15	10	3.5	$h_{FE}:I_C$- 10ma	70	IND
2N1354	5	PNP	Ge	200	300	30	15	4.5	$h_{FE}:I_C$- 10ma	70	IND
2N1355	5	PNP	Ge	200	300	30	20	8.0	$h_{FE}:I_C$- 10ma	80	IND
2N1356	5	PNP	Ge	200	300	30	20	8.0	$h_{FE}:I_C$- 10ma	80	IND
2N1357	5	PNP	Ge	200	300	30	15	12	$h_{FE}:I_C$- 10ma	85	IND
2T3011	3	PNPA	Ge	12W	3.0	40	40	7Kc	$h_{FE}:I_C$-1.0A	70	SONY
2T3021	3	PNPA	Ge	12W	3.0	60	60	7Kc	$h_{FE}:I_C$-1.0A	70	SONY
2T3031	3	PNPA	Ge	10W	3.0	30	30	7Kc	$h_{FE}:I_C$-1.0A	32	SONY
2T3032	3	PNPA	Ge	10W	3.0	30	30	7Kc	$h_{FE}:I_C$-1.0A	50	SONY
2T3033	3	PNPA	Ge	10W	3.0	30	30	7Kc	$h_{FE}:I_C$-1.0A	80	SONY
2T3041		Matched Pair 2T3031									SONY
2T3042		Matched Pair 2T3032									SONY
2T3043		Matched Pair 2T3033									SONY
GFT20	2	PNPA	Ge	80	600	15		.60	$h_{fe}:I_e$-1.0ma	33	TKAD
GFT20R	2	PNPA	Ge	80	600	15		.60	$h_{fe}:I_e$-1.0ma	33	TKAD
GFT20/30	2,5	PNPA	Ge	80	600	30		.60	$h_{fe}:I_e$-1.0ma	33	TKAD
GFT20/60	2,5	PNPA	Ge	80	600	60		.60	$h_{fe}:I_e$-1.0ma	33	TKAD
GFT21	2	PNPA	Ge	80	600	15		1.1	$h_{fe}:I_e$-3.0ma	90	TKAD
GFT21R	2	PNPA	Ge	80	600	15		1.1	$h_{fe}:I_e$-3.0ma	90	TKAD
GFT21/30	2,5	PNPA	Ge	80	600	30		1.1	$h_{fe}:I_e$-3.0ma	90	TKAD
GFT21/60	2,5	PNPA	Ge	80	600	60		1.1	$h_{fe}:I_e$-3.0ma	90	TKAD
GFT22	2	PNPA	Ge	80	600	15		1.35	$h_{fe}:I_e$-5.0ma	150	TKAD
GFT22R	2	PNPA	Ge	80	600	15		1.35	$h_{fe}:I_e$-5.0ma	150	TKAD
GFT22/30	2,5	PNPA	Ge	80	600	30		1.35	$h_{fe}:I_e$-5.0ma	150	TKAD
GFT22/60	2,5	PNPA	Ge	80	600	60		1.35	$h_{fe}:I_e$-5.0ma	150	TKAD
GFT25	2	PNPA	Ge	80	600	15		.85	$h_{fe}:I_e$-2.0ma	50	TKAD
GFT25R	2	PNPA	Ge	80	600	15		.85	$h_{fe}:I_e$-2.0ma	50	TKAD
GFT25/30	2,5	PNPA	Ge	80	600	30		.85	$h_{fe}:I_e$-2.0ma	50	TKAD
GFT25/60	2,5	PNPA	Ge	80	600	60		.85	$h_{fe}:I_e$-2.0ma	50	TKAD
GFT31	2	PNPA	Ge	125	400	15		.40	$h_{fe}:I_e$- 30ma	30	TKAD
GFT31/30	2,5	PNPA	Ge	125	400	30		.40	$h_{fe}:I_e$- 30ma	30	TKAD
GFT31/60	2,5	PNPA	Ge	125	400	60		.40	$h_{fe}:I_e$- 30ma	30	TKAD
GFT32	2	PNPA	Ge	125	400	15		.50	$h_{fe}:I_e$- 50ma	50	TKAD
GFT32/30	2,5	PNPA	Ge	125	400	30		.50	$h_{fe}:I_e$- 50ma	50	TKAD
GFT32/60	2,5	PNPA	Ge	125	400	60		.50	$h_{fe}:I_e$- 50ma	50	TKAD

NOTATIONS

Under Use

1 - Low power a-f equal to or less than 50 mw
2 - Medium power a-f > 50 mw and equal to or less than 500 mw
3 - Power > 500 mw
4 - r-f/i-f
5 - Switching and Computer
6 - Low Noise
↑ - Revised Spec.

Under Type

A - Alloyed
D - Diffused or Drift
F - Fused
G - Grown
H - Hook Collector
M - Microalloy
Me - Mesa
O - Other
S - Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
‡ - Tetrode

Under *s:

* Maximum Frequency
\# Figure of Merit
△ $f_{\alpha e}$
Ø Minimum
† Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_c

Ø - Infinite heat sink

(Concluded on next page)

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics	Gain		MFR. (See code at start of charts)
				P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	PARAMETER and (condition)	VALUE	
GFT34	2	PNPA	Ge	125	400	15		.60	h_{fe}:I_e- 75ma	75	TKAD
GFT34/30	2,5	PNPA	Ge	125	400	30		.60	h_{fe}:I_e- 75ma	75	TKAD
GFT34/60	2,5	PNPA	Ge	125	400	60		.60	h_{fe}:I_e- 75ma	75	TKAD
GFT44/30	2,5	PNPA	Ge	63	800	30		10	h_{fe}:I_e-5.0ma	100	TKAD
GFT45/30	2,5	PNPA	Ge	63	800	30		6.0	h_{fe}:I_e-2.0ma	40	TKAD
GFT3008/20	3	PNPA	Ge		3.75	20		.25	h_{FE}:I_C-500ma	33	TKAD
GFT3008/40	3	PNPA	Ge		3.75	40		.25	h_{FE}:I_C-500ma	33	TKAD
GFT3008/60	3	PNPA	Ge		3.75	60		.25	h_{FE}:I_C-500ma	33	TKAD
GFT3008/80	3	PNPA	Ge		3.75	80		.25	h_{FE}:I_C-500ma	33	TKAD
GFT3408/20	3	PNPA	Ge		3.75	20		.30	h_{FE}:I_C-500ma	60	TKAD
GFT3408/40	3	PNPA	Ge		3.75	40		.30	h_{FE}:I_C-500ma	60	TKAD
GFT3408/60	3	PNPA	Ge		3.75	60		.30	h_{FE}:I_C-500ma	60	TKAD
GFT3408/80	3	PNPA	Ge		3.75	80		.30	h_{FE}:I_C-500ma	60	TKAD
OC169	4,5	PNPAD	Ge	50	600	20		70#	PG at .45Mc	35db	AMP
OC170	4,5	PNPAD	Ge	60	500	20		70#	PG at .45Mc	57db	AMP
OC171	4,5	PNPAD	Ge	60	500	20		100#	PG at 100Mc	11db	AMP
OD650	3	A	Ge		1.2	40	25	.10	h_{FE}:I_C- 15A	24	AEG
OD651	3	A	Ge		1.2	60	40	.10	h_{FE}:I_C- 15A	14	AEG
OD651a	3	A	Ge		1.2	60	30	.10	h_{FE}:I_C- 15A	24	AEG
OD750	3	A	Si		.80	100	50	1.0	h_{FE}:I_C-2.0A	15	AEG
OD751	3	A	Si		.80	100	50	1.0	h_{FE}:I_C-5.0A	15	AEG
OD760	3	A	Si		10	60	40	.50	h_{FE}:I_C-100A	15	AEG
TK70	2	NPNA	Si	300	500	30		5.5	h_{fe}:I_e-3.0ma	50	STCB
TK71	2	NPNA	Si	300	500	30		2.0	h_{fe}:I_e-3.0ma	30	STCB
TK72	2	NPNA	Si	300	500	15		2.0	h_{fe}:I_e-3.0ma	25	STCB
XC121	2	A	Ge	250	200	35	16				ESEB
XC131	2	A	Ge	250	100	35	16	Matched Pair			ESEB

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Under f_{ab}

* Maximum Frequency
# Figure of Merit
△ $f_{\alpha e}$
Ø Minimum
† Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_c

Ø - Infinite heat sink

The following manufacturers have announced that they have begun supplying the indicated previously registered transistors.

CBS-Electronics: 2N235A, 2N235B, 2N236A, 2N236B, 2N242, 2N257, 2N285A, 2N297, 2N297A, 2N306, 2N312, 2N444, 2N445, 2N446, 2N447, 2N556, 2N558, 2N634, 2N635, 2N636, 2N1000
Hughes: 2N356, 2N357, 2N358, 2N388, 2N404, 2N425, 2N426, 2N427, 2N428
Industro: 2N381, 2N382, 2N383, 2N460, 2N461, 2N581, 2N584
Silicon Transistor Corp.: 2N1069, 2N1070
Sylvania: 2N109, 2N405, 2N407
Transitron: 2N117, 2N337, 2N338, 2N656

SEMICONDUCTOR CIRCUIT DESIGN AWARDS RULES

1. Articles and nomographs published in Semiconductor products between April 1959 and March 1960 inclusive will be considered eligible for the awards. It is therefore advisable to submit manuscripts as soon as possible.

2. Mail manuscripts to Semiconductor Products Magazine, 300 W. 43rd St., New York 36, N.Y. Attention: S. L. Marshall, Editor.

Prizes will be 1) an engraved gold medal and $500.00 for the most outstanding Semiconductor Circuit Design Article, and 2) an engraved gold medal and $500.00 for the most outstanding Nomograph relating to Semiconductor Circuit Design.

4. Manuscripts are limited to 3,000 words or less, exclusive of illustrations and diagrams. Manuscripts should be typed double-spaced, and submitted in duplicate. Illustrations and diagrams need not be inked or ruled; however they must be neatly prepared and legible.

5. Judges' decision shall be final, and authors agree to accept these decisions as a condition of entry. Semiconductor Products reserves the right to correct typographical errors that may appear inadvertently in the manuscript.

6. Authors of all published material will be remunerated in accordance with our regular rates. Material found unacceptable will be returned to the authors.

7. Employees of Cowan Publishing Corp. and affiliated companies, and members of their immediate families are not eligible for these awards.

NEW FROM PHILCO

HIGH FREQUENCY NPN SILICON DIFFUSED-BASE TRANSISTORS*

30mc PULSE RATE SWITCHES

60mc AMPLIFIERS

Type Number	h_{fe}	Typical Power Gain	Typical Switching Times (Saturated Test Circuits)
2N1199	12-60 (DC)		t_r 35 mμsec t_s 10 mμsec t_f 25 mμsec
2N1267 2N1268 2N1269	6-18 11-36 28-90	25 db at 4.3 mc	
2N1270 2N1271 2N1272	6-18 11-36 28-90	25 db at 12.5 mc	
Maximum V_{cb}—20 V Maximum temperature—150° C Maximum dissipation—100 MW			

2N1199

This high speed switch has exceptionally low saturation voltage (typically 0.125 V), permitting *practical* design of 5 mc pulse circuits, using conventional saturated switching configurations. 30 mc pulse rates are obtainable in *practical* circuits using non-saturating techniques.

2N1267-68-69

The high gain characteristics of these units make possible the design of high efficiency IF amplifier circuits for communications equipment. These devices have unusually low collector capacitance . . . typically 1.5 $\mu\mu f$ . . . and are available with restricted beta ranges to simplify design problems.

2N1270-71-72

The excellent high frequency response of these transistors makes practical the design of high performance communications systems at frequencies up to 60 mc. They have the same low collector capacitance and are available with restricted beta ranges.

Immediately available for prototype design from your Philco Industrial Semiconductor Distributor.

Write Dept. SC959 Lansdale Tube Company, Division of Philco Corporation, Lansdale, Pa.

**SADT . . . Trademark Philco Corp. for Surface Alloy Diffused-base Transistor.*

Circle No. 19 on Reader Service Card

PHILCO

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

TRANSISTOR CENTER U.S.A.

Announcement

SEMICONDUCTOR PRODUCTS will publish a Limited Printing (1000 Copies) of the

Second Conference
Symposium
on Nuclear Radiation Effects on Semiconductor Devices, Materials, and Circuits

This conference is sponsored by the Working Group on Semiconductor Devices of the Advisory Group on Electron Tubes, Dept. of Defense and will be held at the Western Union Auditorium, 60 Hudson St., New York City, on Sept. 17 and 18, 1959.

To insure yourself of a bound copy of these proceedings you are urged to fill out the reservation form provided at the bottom of this page. The price of this book is $4.50.

Following is a list of the papers scheduled to be delivered at this conference:

- High Energy Electron Irradiation of Germanium and Silicon
- The Nature of a Non-equilibrium Excess Conductance Induced in Silicon by Nucleon Irradiation
- Transient Radiation Effects in Semiconductors
- Positive Ion Bombardment of Metals with Radioactive Kr-85
- Radiation Effects in Compound Semiconductors
- Electron Irradiation Effects in CdS
- Minority Carrier Lifetime of Neutron Bombarded Germanium
- Correlation of Theoretical and Experimental Behavior of Silicon Junction Diodes During Neutron and Gamma Irradiation
- Study Directed Toward Improving the Radiation Tolerance of Silicon Diodes
- Preliminary Study of the Effects of Exposure of Electronics Components to 2-Mev Electrons and Other Kinds of Radiation
- Radiation Effects on Semiconductors
- The Effects of Nuclear Radiation on Some Selected Semiconductor Devices
- Room Temperature Operated Solid State Device for Charged Particle Detection
- Gamma Irradiation Effects on Infrared Detectors
- On The Neutron Bombardment Reduction of Transistor Current Gain
- Analysis of Simple Rectifying and Magnetic Amplifier Circuits During Irradiation
- Transistor Circuit Behavior at Exposures Greater than 10^{15} Fast Neutrons/CM^2
- Radiation Resistant Digital Computer Circuitry
- The Use of Diffused Junctions in Silicon as Fast Neutron Dosimeters
- A Transistor Scaler Circuit For A Megarad Gamma Ray Environment
- Problems of Correlating Radiation Environments
- The Effect of Intermittent Irradiation of the Magnetic Remanence of a Ferrite

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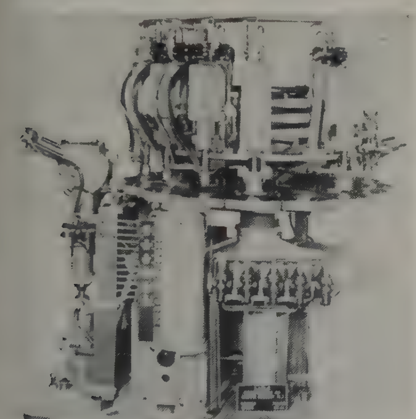
City .... Zone ...... State ....

New Products

Automatic Hole Puncher

The principles of automatic production built into the new Kahle Engineering Company Automatic Hole-Punching Machine #3013 will quite likely find use in many industries where high-speed hole-punching and fire glazing are applied to glass units on any configuration. Has a capacity of 2000 sealed beam headlamp reflectors per hour; punches multiple pre-formed holes, fire-glazes the holes and unloads the reflectors to an annealer. Can be fully synchronized with the press to provide any timing cycle desired. The two-position punching operation performed at 2400 psi at 400° C can be altered to vary the hole pattern, number or size to suit manufacturers' specs. Occupies 5 × 5 ft. floor space, is 6'6" high, approx. 6000 lbs. Can be driven from the forming press or may be equipped with its own power drive. Request data sheet 3013.

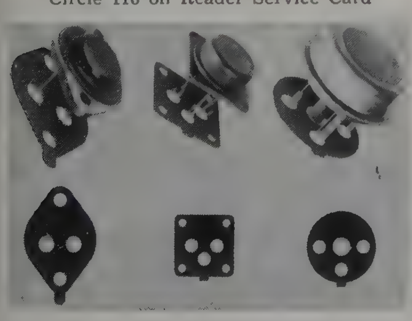
Circle 132 on Reader Service Card



Aluminum Wafers

Hard-anodized aluminum insulator wafers characterized by excellent dielectric resistance and thermal conductivity have been developed for use with power transistors requiring electrical insulation from chassis and dissipation of the substantial heat generated at rated capacities. In diamond, round and square shapes to suit all bases, the aluminum wafers are installed between transistor and chassis, heat sink or other surfaces on which the transistor is mounted. Manufactured by Monadnock Mills, subsidiary of United-Carr Fastener Corporation.

Circle 116 on Reader Service Card



Graphite Tube Furnace

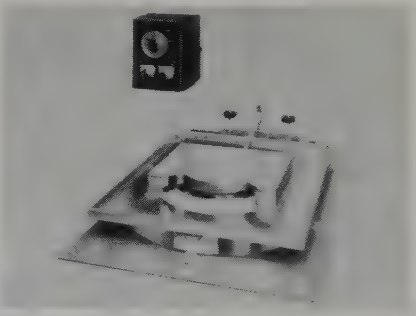
A new high temperature graphite tube furnace has been announced by the Pilot Plant Equipment Division of Lindberg Engineering Company. Type TR25-212C18 has been developed to meet the demands generated by the metals, ceramic and petroleum industries for controlled high temperatures. The overall operating temperature range of 1600 to 5000°F. makes it suitable for a variety of applications including: Sintering of powder metals, High temperature investigations and firing of ceramic bodies, High temperature chemical reactions for the petroleum industry.

Circle 104 on Reader Service Card

Etching Machine

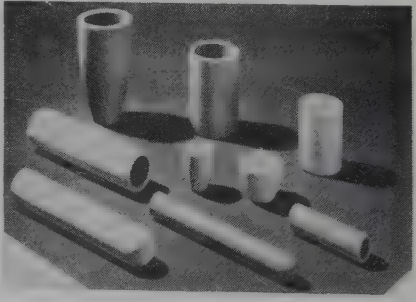
Carman Laboratories announces a new machine for etch-cleaning transistors, rectifiers, diodes & other small parts. Partially completed electronic components are placed in a moving carrier especially designed to expose corroded or oxidized parts to an array of liquid jets. These jets etch-clean and rinse surface contamination from the exposed parts. Processes 1200 to 2400 units per hour. Requires 30" x 22" table-top area and 115 volts A.C.

Circle 133 on Reader Service Card



Pure Oxide Ceramics

Materials for Electronics, Inc., announces Degussit ceramics in pure sintered alumina, sintered spinel, sintered zirconium oxide (stabilized), sintered magnesium oxide and kaolin bonded corundum. These top products of oxide ceramics meet the highest thermal, chemical, mechanical and electrical requirements. Insulating parts made from the pure alumina body (A1-23) are sintered



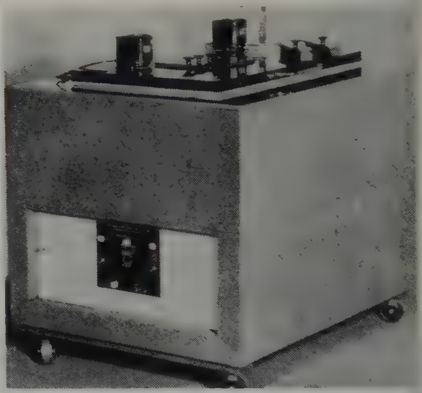
into shapes without the addition of any sintering auxiliaries. The boron content of A1-23 is less than one part per million which makes it suitable for processing of semiconducting materials. The pure alumina body can be delivered in the form of discs, rings, tubes, boats, crucibles as well as special shapes.

Circle 107 on Reader Service Card

Testing Baths

Labline, Inc., has announced production of a new line of variable temperature baths to test diodes, electronic components, thermostats, and other equipment that requires highly accurate testing conditions. These conditions are secured with thermistor controls capable of maintaining temperatures within ±0.1°C accuracy. Produc-temp Baths may be had as individual units each adjustable to 100°C, 25°C, or —55°C; or as a combination with a temperature range from 100°C to —55°C.

Circle 122 on Reader Service Card



Magnifying Lamp

Designed for precision seeing, the Luxo Magnifying lamp, designated Model FLM-1, combines large magnification, cool fluorescent light, and maneuverability into one versatile unit. Features a large precision ground lens with excellent distortion-free 4X magnification. Can be raised, lowered, tilted or turned to any angle to put magnification and cool light where you want it. Leaves both hands free for the job. Fixture is easily turned out of the way when not in use.

Circle 112 on Reader Service Card

Mesa Transistors

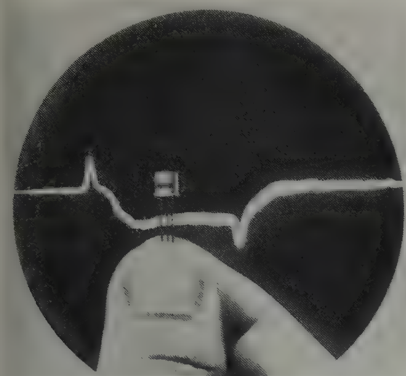
Fairchild announces the 2N699, a high voltage NPN diffused silicon mesa transistor. This two watt unit is rated at 120 volts collector to base, permitting wide voltage swings in amplifier and oscillator circuits. Typical gain-band width product of 120 mc gives excellent broadband video response.

Circle 131 on Reader Service Card

Mesa Switching Transistor

Availability of a new ultra-fast diffused-base silicon "mesa" switching transistor was announced by Texas Instruments Incorporated. Features typical total switching speeds as fast as 25 millimicroseconds. The 2N702 is produced by the gaseous-diffusion process. Dissipates 150 milliwatts at 100° in free air. Provides a guaranteed DC beta spread of 15 to 45 and a maximum collector cutoff current of 0.5 microamps. Minimum breakdown voltage (BV_{CBO}) is 20 volts and maximum saturation voltage is 0.6 volts. It measures only 0.225 inches maximum diameter and 0.205 inches in height not including the 0.520-inch leads.

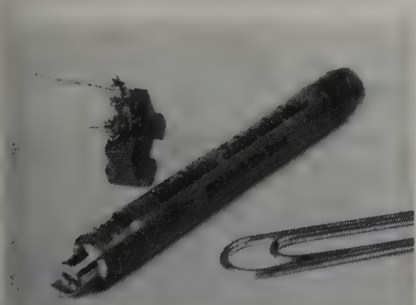
Circle 110 on Reader Service Card



Subminiature Wire Wrapper

This new tool makes reliable wrapped connections to subminiature sockets and transistor sockets and is available from Winkler Laboratories. It is vastly superior to such items as long-nose pliers and tweezers. It can do a better job faster. Connections are uniform, neat and highly reliable. It will accommodate all wire sizes compatible with subminiature terminal size and spacings including #26 AWG and smaller.

Circle 117 on Reader Service Card



Diffused Silicon Rectifiers

Columbus Electronics Corp., has announced the availability, in production quantity, of its new 2000 Volt PIV double diffused silicon rectifiers. Available in the axial lead top hat, 7/16" stud and insulated stud mounts, hermetically sealed. Power supply, magnetic amplifier and blocking applications are listed as typically suitable applications. Specification features include: 1400 to 2000 V. PIV; up to 10 amps rectified current; 1uA leakage at 25°C; 2 V forward drop at 25°C.

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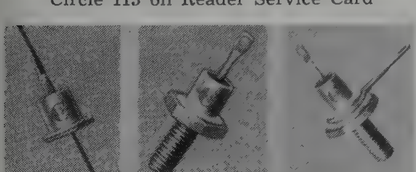
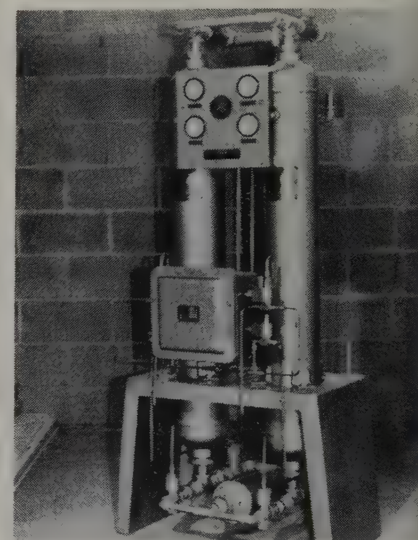


Heatless Air Dryer

Completely automatic, heatless desiccant dryers capable of producing dry air to —200°F dewpoint, are now available for manufacturers of semiconductors, or other electronic assemblies requiring the use of dry-box assembly techniques. The use of dry air completely eliminates the cost and maintenance of the usual bottled gas systems. Trinity Equipment Corporation, manufacturers of Heat-Les dryers and pressurization systems, announce a complete line of dryer units, and complete pressurization systems for the dry-box assemblers.

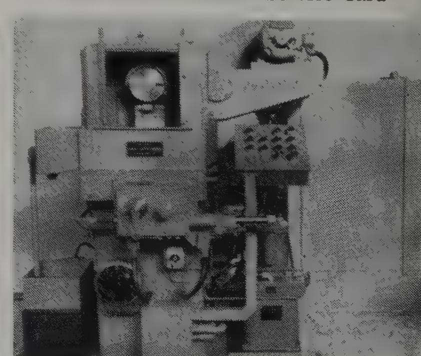
Circle 106 on Reader Service Card



Automatic Slicing Machine

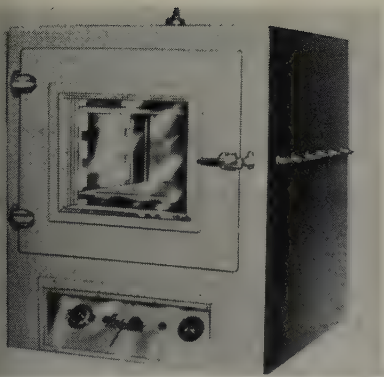
A fully automatic high production machine for slicing semiconductor crystals has recently been developed by the Fitchburg Engineering Corporation. Machine will slice an ingot section up to 4" in length completely automatically. Crystal thicknesses down to .007" plus or minus .0005" are obtainable. All motions may be made independently by hand if desired for special work such as individual rate-grown wafers, etc. Safety interlocking is provided. Hand-Auto selector switch may be locked with a key in Auto position, thus disabling set-up controls. Weighs approximately 2800 pounds.

Circle 109 on Reader Service Card



Forced Draft Oven

Designed with a temperature to 535°F, Electric Hotpack Company forced draft oven is suitable for diode age cycling, drying of transistors and printed circuits, encapsulation, short heat tests and many other temperature conditioning processes for electrical and electronic parts. Standard equipment includes thermostat, wattage selector heat switch and thermometer. Independently circuited over-temperature controller, designed to pro-



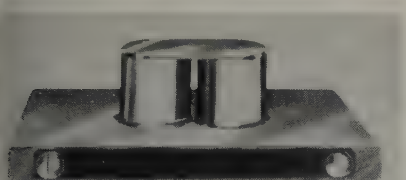
ect work load from accidental heat damage is available. Thru wall terminals optional.

Circle 121 on Reader Service Card

Thermoelectric Junction

Ohio Semiconductors announces a new device, Thermo-cell, type TA-11, thermoelectric junction designed for applications where it is desired to maintain a temperature which is either above or below the ambient. Control applications such as quartz crystal ovens, critical electrical circuits, biological specimens and many other applications where relatively low heat input or extraction is involved, are ideal for the Thermo-cell. Can be used for cooling, heating, power generation and dynamic heat transfer.

Circle 118 on Reader Service Card



Pyro Fuze Wire

A wire has been developed by Sigmund Cohn Corp. which, when heated to about 650°C either by passing current thru it or otherwise, ignites with explosive violence and reaches a temperature of about 2000°C. The total energy developed as heat far exceeds the energy necessary for the inital ignition. The wire is strong and ductile, having a sufficiently high tensile strength that it may easily be handled in most manufacturing operations. B3 Pyro Fuze Wire consists of two separate metals between which an exothermic alloying reaction takes place after a critical temperature has reached. Since it is available in a wide range of sizes to as small as .001", it should be well suited to many special applications including fuze or detonator devices.

Circle 130 on Reader Service Card

PATENT REVIEW

(from page 44)

conductivity type into contact with a molten mixture containing an activating impurity of the opposite conductivity type and maintaining said engagement for a time sufficient to convert a surface of said body to the opposite conductivity type.

2,762,867 Subscriber Telephone Circuit—L. A. Meacham. Assignee: Bell Telephone Laboratories. A subscriber telephone set circuit of the anti-sidetone type having a semiconductor amplifier in the line circuit and a balancing semiconductor amplifier in the anti-sidetone circuit of the set.

2,762,870 Push-Pull Complementary Type Transistor Amplifier—G. C. Sziklai, R. D. Lohman, A. A. Barco. Assignee: Radio Corporation of America; In combination with a pair of semiconductor devices of opposite conductivity type, means for applying a signal voltage of the same instantaneous polarity to the input electrodes and means providing a biasing voltage between the common electrodes for controlling the operation of said devices in balanced relation.

2,762,873 Transistor Bias Circuit Stabilization—H. C. Goodrich. Assignee: Radio Corporation of America. A semiconductor amplifier circuit utilizing a semiconductor device which exhibits the characteristic of providing a phase reversal between the base and collector electrodes.

2,762,874 Semiconductor Signal Amplifier Circuits—A. A. Barco. Assignee: Radio Corporation of America. A semiconductor signal amplifying device that provides a substantially balanced output signal.

2,762,875 Stabilized Cascade-Connected Semiconductor Amplifier Circuits And The Like—J. T. Fisher. Assignee: Radio Corporation of America. A circuit arrangement employing a plurality of cascade-coupled semiconductor devices whereby both the emitter electrode biasing resistors and the impedance of the supply source are bypassed for signal frequencies.

2,762,921 Binary Trigger Circuit—R. A. Henle. Assignee: International Business Machines Corporation. A circuit comprising a bistable circuit, input and output branches, and means effective upon receipt of a signal predetermined polarity at said input branch to shift said output branch from a low to a high output state.

2,762,953 Contact Rectifiers and Methods—I. Berman. Assignee: Sylvania Electric Products Incorporated. An area rectifier including a layer of highly purified germanium, a layer of metal of group III on one surface thereof and an area contact on the opposite surface thereof of a material different from said layers.

2,762,954 Method For Assembling Transistors—M. Leifer. Assignee: Sylvania Electric Products Incorporated. A body of semiconductive material incorporating an upstanding rib between laterally extending surfaces on a base portion, a large area contact engaging said body, and a pair of whiskers engaging said rib from opposite sides, said rib being sufficiently thin to enable interaction between said whiskers.

2,862,955 Transistor Electrode Contacts—G. B. Herzog, G. C. Sziklai. Assignee: Radio Corporation of America. A device comprising a body of semiconductor material, a plurality of electrodes in operative relation with said body and a lead connected to each of said electrodes, said leads being of unequal length to insure selective application of voltages to said leads while the device is being inserted in an operating circuit.

2,762,956 Semiconductor Devices And Methods—R. C. Ingraham. Assignee: Sylvania Electric Products Incorporated. A device comprising a base, leads integrally molded therewith, a whisker element directed away from said base and a semiconductive body carried by a support, said body being engaged by said whisker in point-contact and with a predetermined contact pressure.

2,762,957 High Conduction Diode—B. J. Rothlein. Assignee: SEP. A rectifier including a body of n-type germanium, a wire and a quantity of metal particles confined under pressure between at least part of the end surface of the wire and the germanium.

September 18, 1956

2,763,726 Telephone Ringing-Signal Transmission System—D. C. Weller. Assignee: Bell Telephone Laboratories. A telephone system for transmission between a balanced voice-frequency line at an office terminal and a balanced multiparty voice-frequency at an outlying terminal.

2,763,731 Semiconducor Signal Translating Devices—W. G. Pfann. Assignee: Bell Telephone Laboratories. A device comprising a body of semiconductive material-contact a p-n type construction; two point-contact electrodes on opposite sides of the junction and positioned in such close proximity thereto that the carriers injected by the first electrode directly control the flow of carriers to the second electrode; and a third electrode making an ohmic connection with the zone to which the first electrode is connected.

2,763,771 Single Phase Rectifier Arc Welder—H. J. Bischel. Assignee: Westinghouse Electric Corporation. Arc welding apparatus including a main rectifying circuit, an auxiliary rectifier circuit, said auxiliary circuit being dimensioned to supply current of substantially smaller magnitude than that supplied by the main rectifier so that when current from said main circuit tends to drop below a predetermined magnitude current is maintained through said auxiliary circuit.

2,763,780 Binary Frequency Divider—C. W. Skelton, J. S. Mason. Assignee: Texas Instruments Incorporated. A multiple stage frequency divider circuit in which each basic stage includes a transistor, a resistor, a capacitor, and a saturable transformer, said circuit being well suited for cascade connection to derive consective half-multiples of an input frequency.

2,763,822 Silicon Semiconductor Devices—F. V. Frola, M. W. Slye. Assignee: Westinghouse Electric Corporation. A device comprising a silicon semiconductor, a contact member composed of a metal selected from the group consisting of molybdenum, tungsten, and base alloys, said contact member being disposed adjacent to said semiconductor; and a fuzed layer between said contact and said semiconductor.

✓ Industry News

CONFERENCE CALENDAR

The Following October 1959 IRE and Jointly Sponsored Meetings Are Scheduled:

Sept 30 Oct 1	Industrial Electronics Symposium, Mellon Institute, Pittsburgh, Pa. For Information: Gar Muffly, Gulf Research & Dev. Co., P.O. Drawer, 2038, Pittsburgh 30, Pa. Sponsored By: PGIE: AIEE.
Oct 5-7	5th National Communications Symposium, Hotel Utica, Utica, New York. For Information: Ralph L. Marks, 126 Glen Road, South Mounted Route, Rome, N. Y. Sponsored By: PGCS: Rome-Utica Section.
Oct 6-8	Conference on Radio Interference Reduction, Museum of Science & Industry, Chicago, Illinois. For Information: S. I. Cohn, Armour Research Foundation, 10 W. 35th Street, Chicago 16, Ill. Sponsored By: PGRFI: Signal Corps, Armour Research Foundation.
Oct 7-9	IRE Canadian Convention, Toronto, Canada. For Information: D. K. Ritchie, c/o IRE Canadian Convention, 1819 Yonge Street, Toronto 7, Ontario, Canada. Sponsored By: Region 8.
Oct 12-15	National Electronics Conference, Sherman Hotel, Chicago, Illinois. For Information: Dr. M. E. Van Valkenburg, Electrical Engineering Dept., University of Illinois, Urbana, Illinois. Sponsored By: IRE: AIEE: EIA: SMPTE
Oct 19-21	URSI-Fall Meeting, El Cortez Hotel, Balboa Park, San Diego, Calif. For Information: Mrs. Helen E. Hart, Admin. Asst.—URSI U.S. National Committee, 2101 Constitution Ave., Washington, D. C. Sponsored By: URSI PGAP, PGCT, PGIT, PGMTT.
Oct 26-28	East Coast Aero. & Nav. Electronics Conference, Baltimore, Md. For Information: Dr. R. C. Spencer, The Martin Co., Baltimore 3, Md. Sponsored By: PGANE: Baltimore Section ARDC.
Oct 29-31	Electron Devices Meeting, Shoreham Hotel, Washington, D. C. For Information: Dr. John Hornbeck, Bell Telephone Labs, Murray Hill, N. J. Sponsored By: PGED.

Other Meetings Scheduled:

Sept 21-25	14th Annual Instrument & Automation Conference, International Amphitheatre, Chicago
Oct 6-9	International Symposium on High Temperature Technology, Asilomar Conference Grounds, California. For Information: Stanford Research Institute, Box 734, Menlo Park, Calif.

Oct 11-16 American Society For Testing Materials, Pacific Area National Meeting, Sheraton-Palace Hotel, San Francisco, Calif.

Oct 26-29 Analytical Chemistry, Oak Ridge National Laboratory, Civic Auditorium, Gatlinburg, Tennessee.

NEW DEVELOPMENTS

Halex, Inc., of El Segundo, California, a new corporation pioneering in the field of Molecular Electronics, is specializing in the process of depositing thin films of conductive, semi-conductive and resistive substances to form electronic circuits, according to an announcement made by Harold R. Larsen, President. Halex engineers utilize high vacuum techniques to build up thin films with controlled properties, molecule by molecule, on secondary substances. Thicknesses are readily produced in ranges from less than one millionth of an inch to one hundred millionths of an inch. Through critically controlled processes, specified properties and geometry of almost any material can be achieved. Developments include experimentations with micro-resistors, capacitors, semiconductors, transducers and micro-sensing devices. Eventually, the firm will concentrate on complete replacement circuits to be used in virtually every kind of electronic device.

Scientists at the Westinghouse research laboratories have taken a major step toward the fast, continuous, completely automatic manufacture of transistors and related semiconductor devices. Dr. S. W. Herwald, vice president-research, disclosed that Westinghouse scientists have constructed long ribbons of semiconductor devices by forming them along the surface of long, thin crystals of germanium about an eighth inch wide and a few thousandths of an inch thick. Such construction appears to be feasible for the automatic production of transistors and other solid state devices directly by machine. In addition to the long experimental strips of devices, hundreds of individual functioning units have been prepared from germanium dendrites by the semiconductor department at Youngwood, Pa.

NEW PLANTS

Amperex Electronic Corporation, Hicksville, Long Island, New York, has announced the beginning of construction of a new, two story, modern, air conditioned engineering wing to the present Amperex building. Amperex is engaged in the development, manufacture and distribution of electron tubes and semiconductors for Government, communications and industry. A tremendous increase in research and development work on highly advanced types of tubes and semiconductors, and the addition of new engineering personnel, has made it necessary to markedly increase facilities, according to Mr. Frank Randall, president. Slated for completion in October 1959, the new engineering wing will add 13,000 square feet of working space to the 100,000 square feet of the present building.

TO OUR SUBSCRIBERS:

PLEASE ADVISE CIRCULATION DEPT. IMMEDIATELY OF ANY ADDRESS CHANGE. ONE MONTH IS REQUIRED FOR PROCESSING.

MARKET NEWS . .

Financial

Clevite Corp., sales and profits have reached an all time high during the first six months of 1959. It has reported an earning per share of $1.78 as compared with 59¢ during the first half of 1958. The semiconductor volume of the company was reported to be almost twice that of a year ago. A $ million semiconductor plant is to be constructed shortly in Waltham, Mass.

Daystrom Inc., net in the first fiscal quarter ended June 3 climbed to approximately 40¢ per share as compared with 18 a share for the same period last year. Sales increased some 18% to a first quarter record of $21,250,000 over last year's initial quarter.

International Resistance Co., has reported a 61 percent rise in first-half-year sales over the same period in 1958 and earnings of 67.7 cents per share. International Resistance Company had sales of $9,409,128 for the 25 weeks ended June 2 1959 as against sales of $5,846,958 in the comparable period of 1958. Earnings for the half year of $927,601 contrasted with a loss of $71,248 in 1958.

For its first fiscal quarter (ended May 31, 1959) General Instrument Corporation new profits increased approximately 130% over the same period last year and sales rose 46% to the highest level for any first quarter in the Company's 36 year history. General Instrument sales for the first three months of fiscal 1959-60 totalled $12,728,861 as compared with $8,679,027 for the same period last year. Net earnings were $211,129 or 14¢ per share (on 1,497,723 shares outstanding) more than double the $87,916 or 6¢ per share earned in last year's first quarter period. The first quarter gains were mainly due to rising sales of: semi-conductors (first quarter shipments and backlog were approximately three times those of last year's first quarter); military equipment; TV-radio components.

Industro Transistor Corp., Long Island City, N.Y., recently sold an offering of 100,000 common shares at $5.50 per share.

Stockholders of General Transistor Corp., N.Y., have approved a two-for-one split of its common stock and an increase in the authorized stock from 750,000 to 2 million shares.

The expected split in the share of Texas Instruments Inc. has been postponed by the directors of the company, who felt that, "It is in the best interests of the company and its stockholders not to consider the matter of a split at this time." The values of the shares have been moving up sharply recently.

Estimated net earnings for Motorola Inc., for the second quarter ending June 30th are expected to be about $3,090,000 or about $1.58 per share as compared with $800,515 or 41¢ a share a year ago. Sales for the second quarter are about 65,300,000 as compared with $43,650,070 for the same period last year.

Rheem Manufacturing Company has sold its Defense and Technical Products division "Rel" proprietary line in Downey, Cal. Rheem will continue to engage in the development and manufacture of electronics equipment through its Electronics division in South Gate, Cal., and its four-months-old Rheem Semiconductor Corp. in Mountain View, Cal.

U.S. Semiconductor Products, Inc., of Phoenix, has purchased the adjacent building for $270,000 which formerly was the plant of the U.S. Electronics Development Corp.

A new firm, National Semiconductor Corp. has been established in Danbury, Conn.

Agreement has been reached in negotiations by Telechrome Manufacturing Co. to acquire control of Universal Transistor Products Corp., Westbury, N.Y. Universal has been operating under a court appointed receivership since last February.

Radio Corporation of America's first half earnings for 1959 are $19,400,000 ($1.29 per share). This represents 44% above the sum netted in the first half of 1958. Sales rose to a new record of $633,700,000 in the latest half as compared to $542,-600,000 of a year ago.

Contracts Awarded

General Electric Co., Syracuse, N.Y., $75,000 contract #78346. Research and development for 18 months leading to the establishment of designs for solid-state reciprocal and non-reciprocal filters.

Sylvania Electric Products, Inc., Woburn, Mass. $34,662 contract #84765, 3,180 semiconductor device diodes.

Electromechanical Instrument Division, Consolidated Electrodynamics Corp., received an order from Graybar Electric Co., of $400,000 for transistorized portable test instruments to be used by the Federal Aviation Agency in its air traffic control system.

Transitron Electronic Corp., Wakefield, Mass., $222,111 contract #81286, industrial preparedness measure on transistors.

Servo Corp. of America, New Hyde Park, N.Y. $146,000 contract #81288, industrial preparedness measure for thermistor bolometer detectors.

The U.S. Army Engineers Research and Development Laboratories has granted $45,000 to Colorado State University to continue a three year research program on properties of thin films of metals, semiconductors and insulators.

The Army Signal Corps has awarded to the Radio Corporation of America, Camden, N.J. an additional contract for $2,388,000 for the production system phase of the micro-module program. Under this program the vast range of jobs performed by transistors and other electronic parts is being compressed into circuit building blocks measuring only a third-of-an-inch on either side.

Transitron Electronic Corp., Wakefield, Mass. $21,900 for 10,000 items of diodes type 1N-457, IFB-1079.

Western Electric Co., Inc., N.Y. $93,428 contract #84733; 8,268 semiconductor device diodes.

Microwave Assoc., Inc., Burlington, Mass. $6,200.90 for 2,102 semiconductors ORD-01-021-50-10618.

The Siegler Corporation has been awarded a $100,000 contract from the Sperry Utah Engineering Company, a subsidiary of Sperry-Rand Corporation, for the manufacture of special electronic test gear for the Army's "Sergeant" missile. These units are completely transistorized and miniaturized in aluminum castings, only one-fifth the size of previously available equipment which performed similar testing programs.

Industro Transistor Corp., of Long Island City has doubled its direct labor personnel in the last three months. The company is currently fulfilling a $200,000 subcontract from General Electric Co., for high frequency PNP germanium transistors.

Digital Equipment Corp., Maynard, Mass. transistorized modules (IFB 19-604-59-206) $25,646.00.

Suppliers

American Smelting and Refining Company has installed new facilities at its Perth Amboy, New Jersey, plant which will increase its capacity to produce high purity (99.999%) indium. Asarco has produced high purity indium at its Central Research Laboratories in South Plainfield, N.J., for the past 5 years. Increasing demand for the metal in electronic applications necessitated the completion of larger facilities for the production of commercial quantities.

[from page 17]

ion at the input and output ports, the transducer gain will be a maximum and is given by the expression:

$$G_{T\ max.\ neutralized} = \frac{(y_{21}-y_{12})^2}{4(g_{11}+g_{12})\,(g_{22}+g_{12})}$$

where g_{11} = Real part of y_{11}

g_{22} = Real part of y_{22}

g_s = Source conductance

g_L = Load conductance

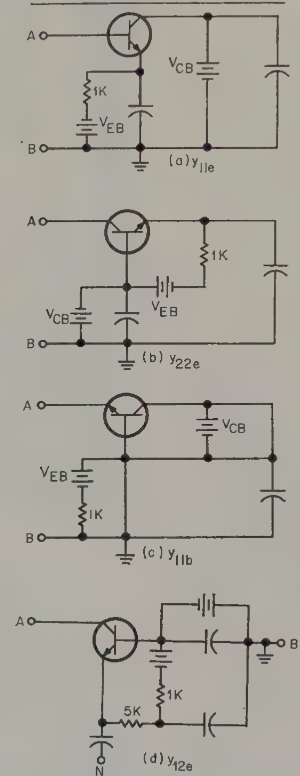


Fig. 15.2—Circuits for measuring the "y" parameters.

PERSONNEL NOTES

Dr. David M. Heinz has been appointed a senior scientist at Hoffman Electronics Corporation's Science Center in Santa Barbara, Calif. Dr. Heinz, as part of a scientific group engaged in research involving new electronic devices and systems, will concentrate on semiconductor materials and in the field of general chemistry. A member of the American Physical Society and Electro-Chemical Society, he holds a B.S. degree in chemistry from the University of Pittsburgh and an M.S. in chemistry from Columbia University. He received his Ph.D. in Inorganic Physical Chemistry in 1954 from the Polytechnic Institute of Brooklyn where his thesis was on the growth of large single crystals of cadmium selinide and related compounds.

E. O. Vetter, an Assistant Vice President since 1958, has been elected a Vice President of Texas Instruments Incorporated effective August 1. Mr. Vetter also assumed, on September 1, the position of division manager of Metals & Controls division of Texas Instruments in Attleboro, Massachusetts, where he has been assigned for the past several months as general manager. He is a graduate of Massachusetts Institute of Technology, a member of the Institute of Radio Engineers and the Instrument Society of America.

Mr. Edward L. Badwick, formerly Production Engineer with Bendix Aviation Corp., Semiconductor Division at Long Branch, New Jersey, has been appointed Plant Manager of Accurate Specialties Co., Inc. new semiconductor component facility at 338 Hudson Street, Hackensack, New Jersey. A graduate of Polytechnic Institute of Brooklyn, he also received his Master's Degree in Metallurgy at Stevens Institute of Technology. He is a member of the American Society of Metals, and the American Institute of Mining and Metallurgical Engineers.

Allegheny Electronic Chemicals Co., recently announced three managerial appointments. Lloyd E. Mount has been appointed manager of the Custom Processing plant. He will be responsible for all single crystal processing of semiconductor materials. Robert J. Stewart has been appointed production manager of Allegheny's Bulk Chemical plant, which currently produces polycrystalline silicon. Edward Sailer has been appointed manager of the Materials Laboratory. He will be responsible for materials evaluation, quality control and customer services.

Arne Christensen has joined the Semiconductor Division of Sylvania Electric Products Inc., as a sales engineer at the company's sales office at Melrose Park, Ill., it has been announced by Ernest H. Ulm, division general sales manager. Mr. Christensen will call upon manufacturers of electronic equipment in the states of Illinois, Wisconsin and Minnesota. He will be responsible for Sylvania's full line of transistors, diodes and rectifiers.

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S-5018 (0.75 AMP)
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20N-3 (1 AMP)
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30LA (1.5 AMPS)
40P-1 (1.5 AMPS)
15P2 (5 AMPS)
30P3 (5 AMPS)
40J2 (10 AMPS)
30RAN (20 AMPS)
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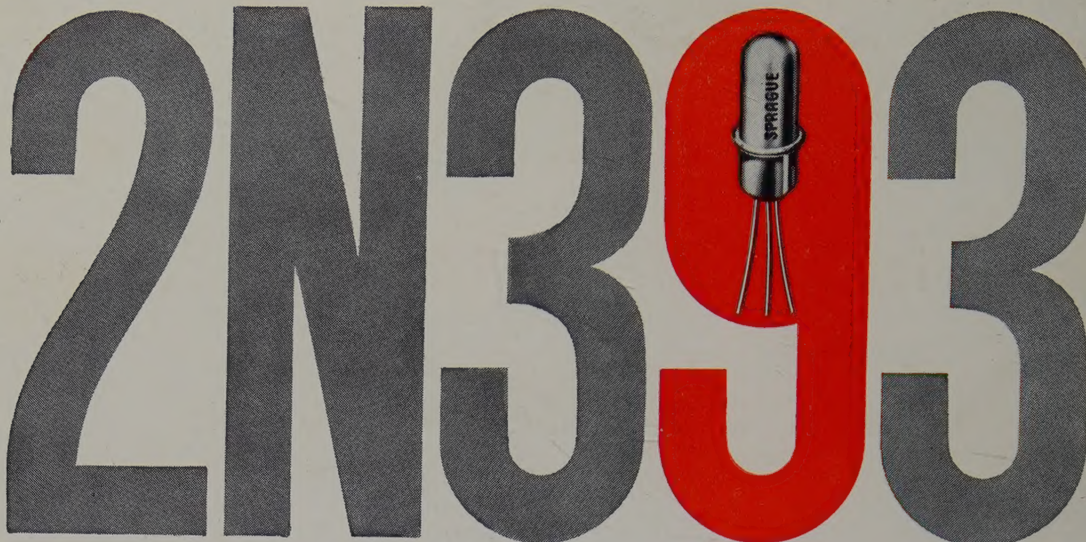

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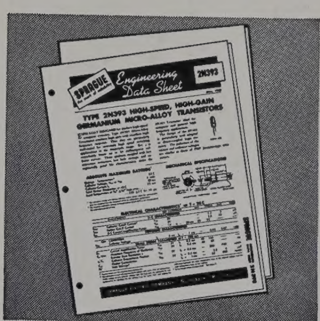

ACTUAL SIZE

2N393

	Min.	Typ.
h_{FE}	20	95
f_{max}	40	60

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